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# *Soil and Water Management Thesis Abstracts*

**Eastern and Southern African Universities**



European Union



University of Malawi

**Compiled by: Implementation and Coordination of  
Agricultural Research and Training (ICART)  
in the SADC Region**



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**Masters and PhD Thesis Abstracts on Soil and Water Management  
Research in Eastern and Southern Africa**

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## **Preface**

It is with great pleasure that I, and the staff of the Southern African Development Community (SADC), Food, Agriculture and Natural Resources (FANR) Directorate, welcome you to this publication entitled – Masters and PhD Thesis Abstracts on Soil and Water Management Research in Eastern and Southern Africa. We are delighted to share with you, this unique compilation of University research arising out of our collaborative efforts with our national, regional, and international partners.

The SADC has as one of its main objectives, increasing agricultural and natural resources production, and ensuring food security. The institutions of higher education and learning in the 15 Member States have an obligation to contribute to the regional development objectives. Substantial research outputs and subsequent knowledge is available from these institutions but is often neglected due to difficulties in accessing the relevant information. Documentation and easy access to existing research information in soil and water management is important for ensuring that lessons from previous research activities inform effective planning and implementation of research and development programmes. The Implementation and Coordination of Agricultural Research and Training (ICART) project together with the 10 Universities in Eastern and Southern Africa under the platform of the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) made the first step in this direction by gathering soil and water management research information in relevant research and training programmes from these universities. The overarching objective was to increase access to university research information by development agencies, researchers and policymakers, and to strengthen networking in soil and water management in the SADC Region.

It is therefore with great pleasure, that I invite you to join us, in safeguarding our natural resource base and fostering sustainable agricultural practices to ensure food security and improved livelihoods of the people of the SADC region.

Dr. Tomaz Augusto Salamao  
Executive Secretary  
Southern African Development Community

## Introduction

Soil and water stresses are by far the most critical limiting factors to sustainable agricultural productivity on small-scale farms, which predominate in sub-Saharan Africa (SSA), a region that is hard hit by the effects of climate change. The overall consequences of climate change have been increased food insecurity and general economic decline in the region. In recognition of this, the African Union has called for increased efforts in extending the area under land and water management (SLWM) in Africa through the Comprehensive African Agricultural Development Programme (CAADP). Nutrient loss through crop harvests and water and wind erosion has led to annual negative nutrient balances in some cases of over 100 kg nitrogen per hectare per year. Recent estimates also indicate that over 500 million hectares of land in Africa are physically degraded, due principally to water and wind erosion (CIAT/TSBF/ICRAF, 2002). All these factors have culminated into declining per *capita* food production estimated previously at 150, to 130 kg per person over the past 35 years. Indeed many institutions have advanced intervention proposals such as “integrated soil and water management”, but there is so far no visible positive change. Sub-Saharan Africa in particular continues to succumb to the retrogressive effects of climate change, namely cyclic poverty and food insecurity.

The Southern African Development Community (SADC,) is particularly concerned with the severe nutrient mining and extended droughts in the region. SADC notes that lack of information of appropriate soil and water management practices is a major factor limiting sustainable crop production among smallholder farmers in the region. In this respect, the SADC-ICART Project, in partnership with the Regional Universities Forum for Capacity Building in Agriculture, considered university research information as a strategic entry-point for identifying solutions for the above challenges; specifically by tapping into the existing soil and water research information in various universities in the region and compiling it into a reference document that can be accessed easily by research and development agencies. Research abstracts of university theses and dissertations in all departments of soil science/management and engineering were seen as an important starting point. This book titled SADC Research Abstracts is a product of this effort.

The work reported in this document was financed by the Southern African Development Community (SADC) Secretariat through the Implementation and Coordination of Agricultural Research and Training (ICART) project with support from the European Union. The ICART project is implemented by the SADC Food Agriculture and Natural Resources (FANR) Directorate with European Union funding. The contents of this document are the sole responsibility of the author and can under no circumstances be regarded as reflecting the position of the European Union or the SADC Secretariat.

**University of Botswana,  
Botswana**

## **Assessment of sewage sludge properties and their agronomic effects on selected soil types in Botswana**

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Sewage sludge generation in Botswana is increasing due to industrialisation and the introduction of advanced wastewater treatment processes. Increase in sludge production requires provision of appropriate disposal options that would guarantee plant, animal and human health and ensure a healthy environment. A disposal in form of use that is gaining popularity is the application of sludge to soil to improve its properties. This study was designed to assess the suitability of the sludge generated at the Gaborone Wastewater Treatment Plant in Botswana as a soil amendment. Two types of sludge: older than three years (Type 1 sludge) and < 3 months old (Type 2 sludge) were applied to 2 Luvisols one each from Barolong and Tuli Block, an Arenosol, from Mmamabula and a Vertisol from Pandamatenga at rates (SAR) of 5:95%, 10:90%, 20:80%, and 40:60% v:v sludge: soil. The mixtures were characterised physico-chemically, chemically and microbiologically immediately after mixing and ninety days later. The mixtures were then potted and planted with spinach and carrots. There was a marked improvement in the soil condition after sludge addition some of which persisted after 90 days. Though the addition of sludge did not change the total heavy metal content of the soils, the partitioning of these metals into chemical pools was altered after 90 days. Addition of sludge increased the load of fecal and total coliform linearly with SAR but ninety days later, the load was reduced with little differences observed with increases in SAR. Spinach performed better on the Type 2 sludge mixtures of Mmamabula, Tuli and Pandamatenga soils sludge mixtures, whereas with the Barolong soils, the Type 1 sludge mixtures yielded more spinach. More carrots on the other hand were produced from the Type 1 than the Type 2 sludge mixtures. Sludge application had little effect on the amount of heavy metals taken up by both plants but influenced the pathogen load with carrots being the more affected. The study also revealed that allowing some time between when sludge is applied to soil and when the soil is planted neutralises the difference in the pathogen load between the Type 1 and Type 2 sludge as well as their ability to attract vectors.

**Key words:** Coliform, heavy metals, human health

## **Influence of livestock kraals on soil nutrient status in a peri-urban area of Botswana**

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This study aimed at investigating the spatial, temporal and vertical influence of cattle kraals on soil nutrient status in areas of actively utilised kraals and abandoned kraals of different ages in a peri-urban area of Botswana. To achieve this, soils were sampled from within the kraals and control sites and analysed to determine their nutrient status. Except with old abandoned kraal

areas (greater than 45 years after the abandonment), soil nutrients in kraal areas showed significantly higher concentrations ( $p < 0.05$ ) than with their corresponding background nutrient gradients. The impact of kraal nutrients was localised to kraal areas and in their immediate vicinity. Soil nutrients declined with age of kraals after their abandonment. Soil nutrient concentrations were higher in winter dry season than in summer wet months. Except in active kraals, soil nutrients were statistically insignificant at surface and subsurface soil horizons.

**Key words:** Age, cattle, nutrient gradients, summer

## **Effect of urbanisation on the flow regime of Notwane Catchment in Botswana**

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Changes in flow regime of rivers as a result of man-made induced modifications of the natural drainage systems is one of the most debated issues between engineers, scientists, water managers and policy makers across the globe. Hydrological processes occurring within the urbanising environments, in particular, continue to receive much attention due to increase in frequency and magnitudes of floods in urban areas. This study evaluated the effect of urbanisation on the runoff co-efficient, which is an associated problem due to introduction of impervious surfaces such as houses, roads and pavements. The catchment used is the Notwane Catchment-Botswana, which covers a major part of the rapidly growing urban centre Gaborone. Two robust methods viz: the Water Balance and the Artificial Neural Networks were used in the study. A multi-cell water balance technique was used to determine runoff coefficient as a function of rainfall, evapotranspiration and field soil moisture capacity during 1978 and 2000. Average runoff coefficient for the whole catchment changed from 0.48 to 0.51 over the last two decades (1981-1990 and 1991-2000), i.e. 6% increase and 0.49 to 0.51 (i.e. 4%) for the same period based on observed flows. In the case of the urban increase was 6% for the same decades. Statistical analysis of Water Balance computed values, though showed very marginal increasing trend ( $\hat{\delta} = 0.0234$ ), did not show any severe interventions to the time series. Rainfall decreased in the order of 0.0146 (1 mm year<sup>-1</sup>) with evapotranspiration increasing by 0.0029 (13 mm year<sup>-1</sup>) for the same period. Simulation studies, taking into account the present scenarios of climate change and the changes in land use due to urbanisation showed that runoff coefficient might reach an average value of 0.54 at the end of 2010. Based on the simulations using The Artificial Neural Networks, runoff coefficients showed an increase of 2% between the last two decades (1981-1990 and 1991-2000), i.e. average increase from 0.49 to 0.51. It was revealed that runoff coefficient will increase by an average of 4% of 0.53 for the next two decades (2011-2020). Though this might appear insignificant, caution should be taken to avert flood risks. Between 1978 and 2000, it was found out that 52% of the changes in runoff for the catchment were attributable to land use-drainage changes, while 48% was due to changes in climatic variables.

**Key words:** Evapotranspiration, rainfall, soil moisture, urbanisation

**University of Zimbabwe,  
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## Effect of land use on natural and disturbed vegetation systems in Harare, Zimbabwe

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The effects of land-use on biomass and biodiversity of vegetation systems and soil characteristics were determined at Pension, Churu and the University of Zimbabwe Research Farms near Harare, Zimbabwe. Pension farm has been under Kikuyu (*Pennisetum clandestinum*) and star (*Cynodon nlemfuensis*) grass pasture irrigated with sewage effluent since 1979; while Churu farm is under natural pasture. The selected sites represented Miombo Woodland (UZRF-Mio), Eucalyptus plantations (UZRF-Euc) and Savanna Grassland (UZRF-Gra) at the University of Zimbabwe Farm are red clay soils on the same catenal position. Vegetation biomass and diversity were determined in March 2007. Soil sampling was done over November 2006 to March 2007. Soil samples were collected from each land use system to determine organic carbon mineral and total nitrogen, pH and soil moisture. Total grass and herbaceous biomass was highest at UZRF-Euc followed by UZRF-Mio with means of 131.6, 86.5 and 24.2 g m<sup>-2</sup> respectively. At Churu farm total biomass ranged from 29.16 to 62.54 g m<sup>-2</sup>, while it ranged from 13.36 to 45.21 g m<sup>-2</sup> at Pension Farm. At UZRF-Mio *Brachystegia spiciformis* and *Parinari curatellifolia* were the dominant woody tree species on the basis of total stem count (300 and 200, stems, respectively). However, UZRF-Euc had a higher basal area. UZRF-Gra and UZRF-Mio had high species richness of 25 and 22 species, respectively; while UZRF-Euc had a species richness of 14 species. Churu farm species richness decreased down the slope at 14, 8 and 6 species for the respective topographic positions, i.e., upslope (Chu-up), mid-slope (Chu-mid) and Low slope (Chu-low). The same trend was observed for Pension farm, i.e., 9, 5 and 3 species for the respective topographic positions, i.e., upslope (Pen-Up), mid-slope (Pen-mid) and low slope (Pen-low). At the UZRF wooded sites, UZRF-Mio had higher species richness (6 species); while UZRF-Euc had a species richness of two species. The Shannon index showed that the dominant species had the highest values, i.e., *Brachystegia spiciformis* and *Parinari curatellifolia* indices of 0.37 each. At UZRF, *Eucalyptus globules* and *E. camaldulensis* had indices of 0.33 and 0.36, respectively. Soil pH was slightly acidic to neutral at the sites, ranging from 5.0 to 6.2. Gravimetric soil moisture increased as the rainy season progressed at non-irrigated sites, reaching a maximum of 11.5%. However, at Pension Farm, gravimetric soil moisture was high (up to 35%) throughout the season due to continuous irrigation. Soil organic carbon was higher (mean 2.33%) at the effluent loaded Pension Farm sites compared to rain fed Churu farm pastures (1.05%). UZRF sites were relatively high in carbon, due to high clay contents. UZRF-Gra had a mean percent carbon of 2.1, UZRF-Mio of 1.0% and UZRF-Euc of 1.1%. Ammonium-N increased significantly ( $p < 0.001$ ) at the UZRF sites when the rainy season began. Mean ammonium-N was 4.1, 0.9 and 5.7 mg kg<sup>-1</sup> at UZRF-Gra, UZRF-Mio and UZRF-Euc respectively. Ammonium-N was highest at Pen-low, reaching a maximum of 22.4 mg kg<sup>-1</sup>. Mean ammonium-N at Churu farm was 4 mg kg<sup>-1</sup>. The soil nitrate-N peaked in December 2006 with UZRF sites averaging 0.9 mg kg<sup>-1</sup>. Pen-mid and Pen-low were highest reaching up to 9.8 mg kg<sup>-1</sup>. Churu Farm sites were low in nitrate-N (mean 0.11 mg kg<sup>-1</sup>) as well as Pen-up. At UZRF-gra, mean total N was 0.3% while at UZRF-Mio and UZRF-Euc mean total N was 0.2%. At Churu-up, N had a mean of 0.24%, 0.3% at Chu-mid and 0.4% at Chu-low. Soil N was 0.5% on average at Pen-up and Pen-mid, while at Pen-low it was 0.6%.

**Key words:** *Eucalyptus* sp., Miombo Woodland, *Pennisetum clandestinum*

## **Composting of chicken blood and maize stover as waste management strategy to produce a nitrogen rich soil amendment**

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Chicken slaughter results in the production of a lot of blood that is difficult to dispose of as it poses a lot of environmental hazards. There is, thus, the need to find an alternative disposal method that is environmentally friendly. The aim of the study was to develop an aerobic composting process for chicken blood to produce a nitrogen rich soil amendment. Characterisation of chicken slaughterhouse waste was done through a structured questionnaire. Blood, feathers, offal, poultry litter, wastewater, waste paper, settling sludge, rotten birds and dead on delivery birds were found to constitute slaughterhouse waste. The amounts could not be determined as the waste was not weighed before disposal. The waste was managed through disposal at landfills or sold to local residents as manure. Blood is the most difficult to dispose as land application has a lot of negative environmental impacts. Composting of blood and maize stover of different proportions (10, 30, 70 and 100% maize stover) was done in compost bins over 72 days. The performance of the different compost was evaluated by monitoring internal temperature, mineral -N ( $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N), C/N ratio, pH, EC and total cations. The 10 and 30% maize stover treatments got into the active phase of composting within 72 hours, which lasted for 8 days; while the 70 and 100% did not achieve thermophilic temperatures. The concentration of ammonium-N decreased from 160, 126, 84 and 43 ppm to 146, 62, 56 and 35 ppm for the 10, 30, 70 and 100% respectively. Composting time and all treatments were significantly different from each other ( $p < 0.001$ ). Nitrate-N peaked to 1.93 and 1.06 ppm for the 30 and 70% treatments, respectively on day 43; while it peaked to 1.54 and 0.54 ppm for the 10 and 100% respectively on day 50. These peaks occurred when temperature as  $40^\circ\text{C}$ . All treatments were significantly different ( $p < 0.001$ ). The C/N ratios decreased to 13.52, 13.92, 22.84, 52.50 for the 10, 30, 70 and 100%; respectively. Total cations and pH did not vary much with composting time. The treatments were however significantly different. Electrical conductivity increased from 2.61, 2.14 and 1.69  $\text{mS cm}^{-1}$  to 4.05, 3.46, 2.85 and 2.14  $\text{mS cm}^{-1}$  for the 10, 30, 70 and 100%, respectively. The pot experiment involved planting 10 maize seeds in each pot. Germination percent was determined a week after germination to ascertain whether the final compost had phytotoxic effects. Percent germination did not differ significantly among treatments ( $p = 0.26$ ). Nitrogen uptake differed significantly and ranged from 0.27 to 75%. Nitrogen uptake was high in the soils amended with compost derived from the 10 and 30% maize stover treatments. Uptake of cations did not differ among treatments. The 10 and 70% treatments had better composting performance than the 70 and 100% treatments based on temperature profiles and changes in mineral-N and C/N ratio. Finished composts derived from mixtures of chicken blood and maize stover a initial proportions of 10 and 30% maize stover had greater potential to support plant growth.

**Key words:** Blood, composting, slaughter house, sludge

## Characterisation of rhizobia nodulating promiscuous soyabean in some Zimbabwean soils

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The presence of effective indigenous rhizobia nodulating promiscuous soyabean could alleviate the need for inoculation in some communal areas of Zimbabwe, where there is inadequate distribution of commercial inoculants. This study was carried out to determine the distribution, population sizes, morphological and physiological properties as well as host ranges and symbiotic effectiveness of rhizobia that nodulate promiscuous soyabean. Presence of indigenous rhizobia nodulating promiscuous soyabean was determined in ninety two mainly sandy soils from agro-ecological regions 2 and 3 of Zimbabwe. Promiscuous nodulating soyabean varieties, Magoye and 'Local' and four commercial specific varieties Roan, Soma, Solitaire and Sonata were tested for their ability to nodulate under field conditions. Magoye nodulated in 79%, Hernon 147 in 50% and Roan in only 31% of the 92 soils tested. Under field conditions promiscuous varieties Magoye and Local nodulated effectively in all the six soils tested but specific varieties only nodulated at most in three soils. Rhizobia populations ranged from 1 to  $2.4 \times 10^4$  cells  $g^{-1}$  of soil in 19 of the 33 soils tested of which seven had a soyabean history and were mainly from Guruve and Chiweshe. There is potential to grow promiscuous soyabean varieties without inoculation in Guruve and parts of Chiweshe. Fast growing isolates failed to re-infect the original soyabean host and were discarded. Isolates (129) from nodules of Hernon 147, Magoye and Roan were characterised using growth rate, elasticity, colour, size and shape of their colonies as well as acid/alkali production on YEM, pH, temperature and salt tolerance. Cluster analyses using the simple matching coefficient ( $\%S_{sm}$ ) were used to group isolates. Isolates separated into 2 major clusters at a similarity level ( $\%S_{sm}$ ) of 66%. Cluster I contained isolates forming dry colonies (77%) which separated into 9 groups and cluster II contained those forming the wet colonies (23%) with 4 groups. Acid and salt tolerance patterns did not differ among the two main clusters (the dry and wet colony types). More isolates forming wet colonies (47%) survived at 40°C than those forming dry colonies (13%). The salt, temperature and soil pH tolerance was not related to area of origin of the isolates. The promiscuous soyabean variety Magoye nodulated with the widest range of rhizobia (12 groups) followed by Hernon 147 (11 groups) and then Roan (9 groups). Guruve soils had the most diverse range of isolates belonging to 12 groups followed by those from Chiweshe (9 groups) and then those from Chikomba (8 groups). Of the 34 isolates tested for the host range, 33 formed nodules with *M. atropurpureum* of which 61% were moderately effective to very effective while all nodulated *V. unguiculata* with 58% being moderately effective to very effective. Twenty eight isolates nodulated *V. suserranea* and *C. cajan* (short season variety) with 76 and 36% of these being moderately to very effective, respectively. None of the isolates formed nodules on *Phaseolus vulgaris*, *Arachis hypogea* and *Sesbania sesban*. Symbiotic effectiveness tested on 21 of these isolates showed significant differences in nodule numbers, nodule weights and total N fixed. Magoye formed the largest nodules of the varieties tested. Based on total N, three indigenous isolates had significantly higher N fixing potential in comparison with the commercial strain MAR 1491 on Magoye.

**Key words:** *Arachis hypogea*, *Phaseolus vulgaris*, *Sesbania sesban*

## **Optimising selected agronomic practices to enhance yields in maize and soyabean rotation systems under smallholder cropping conditions**

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Smallholder (SH) soyabean yields averaging 0.8 t ha<sup>-1</sup> are low compared to the 2-3 t ha<sup>-1</sup> obtained under large scale commercial production in Zimbabwe. Agronomic practices such as rhizobial inoculation rate, seeding rates, planting dates and fertiliser management need to be optimised for SH cropping conditions through appropriately targeted research. A trial was set up during the 2001/2002 season in Guruve and Goromonzi districts, on sandy soils, to assess the effect of increased inoculation rates on nodulation and grain yields of soyabean. Two soyabean varieties Solitaire and Storm were inoculated with commercial rhizobial inoculants containing *Bradyrhizobium japonicum* (strain MAR 1491) at the five different rates. Nodulation and grain yields increased with inoculation rates for both varieties ( $p < 0.05$ ). Grain yields for variety Storm doubled at both sites with a five times increase in inoculation rate. For variety Solitaire, a five times increase in the recommended rate of led to a 60% increase in grain yields. Results showed that the recommended inoculation was insufficient for maximum nodulation and grain yield for soyabean grown on sandy soils. Results suggest that farmers could increase returns by a factor of 30% when the inoculation rate is increased five times. The higher inoculation rates would require more inoculant production facilities to be set up to meet increased demand. The effect of row spacing on grain yields of late planted soyabean varieties (Storm and Magoye) was assessed through a trial set up at the University of Zimbabwe farm on clayey soils and in Goromonzi district on loamy sand soils during the 2001/2002 season. Soyabean was planted in three inter-row spacings on five different planting dates; within and after the recommended planting period. Results show that for both varieties, narrow rows 30 cm apart give higher grain yields compared to wider spacings for late planted soyabean crop on the clayey soils at UZ farm ( $p < 0.05$ ). On sandy loam soils, no yield advantage of narrow rows was observed. To assess the profitability of two maize/soyabean rotation systems for which all basal amendments were applied on the first year crop, a trial was set up during the 2000/2001 and 2001/2002 seasons in Goromonzi district on sand and sandy loam soils. Soyabean variety Solitaire and maize variety SC 403 were used as test crops. Basal treatments applied to both crops in the first season were 15t ha<sup>-1</sup> manure and 150 kg ha<sup>-1</sup> compound L (5% N, 18% P<sub>2</sub>O<sub>5</sub>, 10% K<sub>2</sub>O and 0.25% B). No basal amendments were applied on the subsequent crop. In both seasons, maize and soyabean grain yields were higher at the site with sandy loam soils than at the site with sandy soils. Overall, gross margins for the two seasons were higher when basal amendments were applied on soyabean at both sites. At the site with sandy loam soils, where manure and mineral fertiliser were applied as basal on soyabean followed by maize, gross margins were 1.8 and 1.9 times higher than the control, respectively. When all basal amendments were applied on soyabean, returns obtained at the site with sandy loam soils were 9 times higher compared to the sandy site. On the sandy loam soil applying basal amendments on maize gave positive gross margins in both years.

**Key words:** Inoculation, grass margin, mineral fertiliser, sandy soil

## **Exploring variability in soil fertility, crop yields and nutrient use efficiencies in smallholder areas of Zimbabwe**

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Complex variability in soil fertility within and across farms poses a major challenge for increasing resource use efficiency and overall crop productivity in smallholder farming systems. A study was carried out to assess the effect of farmers resource management strategies on variability in soil fertility and plant nutrient uptake on smallholder farms in Gokwe South and Murewa districts of Zimbabwe. At each site, farmers were grouped into three resource-endowment classes, resource endowed (RG1) intermediate (RG2) and resource constrained (RG3) on the basis of cattle, implement and land ownership. In Murewa, wealthy farmers (RG1) who owned cattle concentrated large amounts of manure on fields closest to their homesteads (homefields) and applied none to fields further away (outfields) which led to gradients of decreasing soil fertility with increasing distance from homesteads. Soil available P and N and OC were particularly responsive to management irrespective of soil type in Murewa. Available P was more concentrated on homefields on wealthy farms (average of 26.6 mg kg<sup>-1</sup>) compared to outfields and all plots on poor farms (2-6 mg kg<sup>-1</sup>). Total N available and P, pH and CEC were generally higher in Gokwe than Murewa. An inverse of soil fertility gradients was observed on Gokwe soils with total N, OC and available P as these were higher in outfields as compared to homefields regardless of soil type. Maize grain yields at both study sites were largest on the homefields on the wealthy farms (2.7-5.0 t ha<sup>-1</sup>) but poor across all fields on the poor farms (0.3-1.9 t ha<sup>-1</sup>). Plant analyses showed P deficiencies in Gokwe as P was less than the critical amount of 0.15% on all soil and field types. Zn concentrations were in the low range (15-20 mg kg<sup>-1</sup>) on both soil and field types in Murewa. Maize grown on homefields in Murewa and all fields in Gokwe responded to addition of N and P in the greenhouse pot experiment. Field trials showed that grain yields were consistently higher on homefields compared to outfields in all treatments on both soil types. In the short-term experiment on the clayey soils, maize grain yields responded significantly to addition of N and P fertiliser. Yields ranged from 3.5 to 5.1 t ha<sup>-1</sup> on the clayey and 1.2 to 4.5 t ha<sup>-1</sup> on the sandy soils. The long term trials showed that greatest yields of about 6.1 t ha<sup>-1</sup> were achieved on the clayey homefield with 100 kg N ha<sup>-1</sup> and 30 kg P ha<sup>-1</sup> applied as SSP. Macronutrients and Ca additions to SSP treatments in the long term experiments did not significantly increase maize grain yields and were relatively lower compared to manure treatments especially on the degraded sandy outfield. Application of 10 kg P ha<sup>-1</sup> regardless of source had a significant effect on grain yield with maximum yield attained at this rate (1.4 to 1.9 t ha<sup>-1</sup>) with SSP and manure on the sandy outfields. This study highlights the need to consider key factors driving variability in soil fertility such as soil type, farmer management practices period under cultivation and agro-ecology when making recommendations for fertiliser use.

**Key words:** Manure, nitrogen, nutrient uptake, phosphorus

## **Environmental effects of wastewater quality and management on soil and horticultural production in Harare**

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Contamination of soil and leafy vegetables (*Brassica juncea* and *B. napus*) with copper (Cu), zinc (Zn), cadmium (Cd), nickel (Ni), chromium (Cr) and lead (Pb) and the subsequent human exposure risks were determined at three gardening sites in Harare where wastewater had been applied for at least 10 years. Total heavy metal concentrations ( $\text{mg kg}^{-1}$ ) in soils ranged from 7.0-1.45 for Cu, 14-228 for Zn, 0.5-3.4 for Cd, 0-21 for Ni, 33-225 for Cr and 4-59 for Pb in the 0-20 cm soil depth, depending on site and position of the gardens. Heavy metal concentrations were considerably higher in the soil of wastewater irrigated gardens than in the non-irrigated (control) soil (0-20 cm), and the subsoil (30-50 cm) of wastewater-irrigated gardens. The annual loading rates of the studied heavy metals exceeded their permitted limits in soils on which treated sewage and sludge mixture was applied. The concentrations ( $\text{mg kg}^{-1}$  dry wt) in garden vegetable leaves at all sites ranged from 1.0-3.4 for Cu, 18-201 for Zn, 0.7-2.4 for Cd, 2.5-6.3 for Ni, 0.7-5.4 for Pb and 1.5-6.6 for Cr. Bio-concentration factors ranging from 0.01-2.7 were obtained and Cd and Zn had the highest factors. The estimated daily intakes of heavy metals from leafy vegetables were above their minimum risk level for Cd and were more than 40% of their minimum risk levels for other studied heavy metals except Cu and Zn at all sites. A greenhouse study using *B. juncea* showed that the uptake of all studied heavy metals except Pb significantly ( $p < 0.05$ ) increased with the level of soil contamination during the early stages of growth (6 weeks after planting).

**Key words:** *Brassica juncea*, Cadmium, Chromium, lead

## **Response of maize and soyabean to N and P fertilisation as influenced by soil acidity**

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There is widespread evidence on the global increase in soil acidity in Zimbabwe and its detrimental effects are well documented. Comparatively, little attention has been paid to the significance of high acidity in reducing nutrient uptake (N and P) and growth of maize (*Zea mays*) and soyabeans (*Glycine Max* L.). A study was conducted to determine the level of awareness on liming and the range and amounts of liming materials used by small household (SH) farmers in Chendambuya. Farmers' awareness to soil acidity was evaluated in the form of a survey. Results from the survey showed that farmers were aware of soil acidity (62%), but they were not well informed (less than 30% were aware of soil acidity) about its causes and importance of amelioration. Only 7% of the farmers used lime. In a greenhouse study, maize was grown in a modified 1:5 Steinberg solution at 0, 4, 8, and 16  $\text{mg L}^{-1}$  Al. Phosphorus was applied to the nutrient solution at 3, 4 and 5  $\text{mg L}^{-1}$ . In the sensitive variety severe reduction in dry matter yield (74%) occurred at Al concentrations of 8  $\text{mg L}^{-1}$ , while in the sensitive variety severe reduction (60%) was at 16  $\text{mg L}^{-1}$ . For the tolerant variety, the final pH values were higher than the initial value of 4.8, while they were lower for the sensitive variety. It was concluded that Al tolerance in SC403 was attributed to a high pH in the rhizosphere, while

sensitivity in SC517 was attributed to greater solubility in the rhizosphere due to low pH. Field trials were also conducted to determine low soil acidity affects on N and P uptake by maize and soyabeans. For the maize experiment, 3 N rates (0, 30 and 60 kg N ha<sup>-1</sup>) were combined with two P rates (0 and 30 kg P ha<sup>-1</sup>) and 2 lime rates (0 and 600 kg ha<sup>-1</sup> for sandy soil, 0 and 1,500 kg ha<sup>-1</sup> for sandy clay loam soil) on two sandy soils and one sandy clay loam soil. For the soyabean experiment 4 P rates (0, 7.5, 15 and 22.5 kg P ha<sup>-1</sup>) were combined with two N rates (0 and 30 kg N ha<sup>-1</sup>) on a sandy clay loam site. Application of lime did not improve dry matter and grain yield ( $p > 0.05$ ) of both the maize and soyabean. For the maize crop, N and P application improved growth, nutrient uptake and grain yield with a higher response at the sandy sites. The average grain yield increased by 28, 35 and 14% at Mwendazviya, Domboshawa and Kunamira sites, respectively, on addition of P. In the soyabean experiment, liming improved nodule number and nodule dry matter yield by an average of 56 and 81%, respectively. Phosphorus application rate enhanced nodule development, while N fertiliser application suppressed the development and growth of nodules. Application of CAN reduced nodule number by an average of 34 and 96% in the first and second seasons, respectively.

**Key words:** Aluminium, *Glycine max*, *Zea mays*

### **Manure and soil properties effects on survival and persistence of soyabean nodulating rhizobia in smallholder field environments of Zimbabwe**

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Persistence of the commercial soyabean inoculant strain MAR 1491 was assessed in 52 soils from Guruve, Hurungwe and Goromonzi districts in Zimbabwe that had last been planted to inoculated soyabean in 1996, 1998, 1999 and 2000. Most probable number estimates of rhizobia in these soils showed a decrease in population sizes with increasing number of years since the last inoculation. Rhizobial soil populations of up to 10<sup>2</sup> cells g<sup>-1</sup> soil were found in Guruve soils inoculated 3 years before, while rhizobial persistence in Hurungwe and Goromonzi soils was significant for soils inoculated 2 years before ( $p < 0.001$ ). The greater persistence of rhizobial strains in Guruve soils was attributed to high clay (>20%) and organic C (>1%) in the Guruve soils compared with the sandier less fertile Hurungwe and Goromonzi soils. Rhizobia require C for energy. High clay in a soil also protects rhizobia from unfavourable environmental conditions such as heat and improves moisture holding capacity of the soil, enhancing rhizobial survival. Results showed that in Guruve farmers could grow two more soyabean crops in a soyabean-cereal rotation without the need for re-inoculation while Hurungwe and Goromonzi farmers can only grow soyabean for one additional year after inoculation. The effects of manure on survival and persistence of the inoculant strain MAR 1491 was tested at two sites in Goromonzi district that received manure applications at rates of 0, 5 and 10 t ha<sup>-1</sup>. Manure increased rhizobial numbers from just 10 cells g<sup>-1</sup> soil in November 2000 before manure application to 10<sup>3</sup> cells g<sup>-1</sup> soil in January 2001 after manure additions. Increases in rhizobial numbers were attributed to high organic C content of 38% of the manure used. Rhizobial population increases also closely followed the progress of the wet season. The highest rhizobial soil population of 10<sup>5</sup> cells g<sup>-1</sup> soil was obtained in the 10 t ha<sup>-1</sup> manure treatment in March 2001 when the highest soil moisture of 15% on weight basis was recorded, while the lowest rhizobial population of 10 cells g<sup>-1</sup> soil was recorded at 0 t ha<sup>-1</sup> manure in June 2001 when the lowest soil moisture of <2%

was measured. Farmers could benefit from using cattle manure since it provides soil C, thereby enhancing rhizobial survival and persistence in soils. Ten promiscuous soyabean isolates that proved superior in N-fixation to the commercial inoculant strain MAR 1491 were also tested for their symbiotic performance under field conditions. Out of these, only four isolates, i.e., M3 (from promiscuous soyabean variety Magoye) and H1, H3 and H5 (from the promiscuous variety Hernon) were superior in N<sub>2</sub> fixation to the reference strains MAR 1491 and 1495 with Magoye and specific soyabean variety Solitaire, respectively. These four isolates have potential for use as commercial inoculants.

**Keywords:** Cereal rotation, clay, inoculation, organic carbon

### **Mineralisation, microbial biomass and enzyme activities in soils amended with leaves of multipurpose trees**

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Mineralisation of carbon and nitrogen from decomposing leaves of multipurpose tree species *Gliricidia sepium*, *Acacia angustissima*, *Acacia karoo*, *Acacia nilotica* and *Colophospermum mopane* in a sandy soil was measured in an 8 week laboratory incubation experiment. Mineralisation of 1:1 mixtures of *G. sepium* with each of the other four species was also evaluated. Response of sorghum (*Sorghum bicolor*) shoot dry matter yield and N recovery from multipurpose trees (MPTS) soil amendments were determined in a glasshouse pot experiment. Laboratory incubation experiments were conducted to determine microbial biomass carbon and enzyme activities during decomposition of the leaves in the soil. Carbon mineralisation was in order from the fastest *G. sepium* + *A. angustissima* > *G. sepium* > *A. angustissima* > *G. sepium* + *A. karoo* > *G. sepium* + *C. mopane* > *G. sepium* + *A. nilotica*. Net N mineralisation was observed in soil amended with *G. sepium* and the mixture *G. sepium* + *A. angustissima*. *Acacia angustissima*, *A. karoo*, *A. nilotica* and *C. mopane* immobilised N. *Gliricidia sepium* + *A. karoo* and *G. sepium* + *C. mopane* initially immobilised N for 2 weeks and thereafter mineralised N throughout the incubation period. *Gliricidia sepium* + *A. nilotica* immobilised N for 5 weeks. These patterns suggest that mineralisation of *G. sepium* can be manipulated by mixing it with different MPT leaves. Sorghum shoot dry matter was responsive to amending soil with MPT leaves contrary to the hypothesis that it is less sensitive to changes in nutrient availability. Shoot dry matter yield was in the order of *G. sepium* > *A. angustissima* > control > *A. karoo* > *C. mopane* > *A. nilotica*. While 20 and 8% of N initially added as *G. sepium* and *A. angustissima* leaves was, respectively, recovered in the sorghum shoots, negative recoveries were observed in soils amended with *A. karoo*, *A. nilotica* and *C. mopane*. A maximum of 18% leaf C was incorporated into the biomass in soils amended with *G. sepium* leaves at 3 days from start of incubation and 3% for *A. nilotica* at 7 days. Biomass carbon in *A. karoo* amended soil initially increased to a maximum of 3% at 7 days. After declining to about 1% at day 14, biomass carbon in *A. karoo* amended soil increased to a maximum of 5% at day 28. *Colophospermum mopane* attained a maximum of 5% leaf C being incorporated in the microbial biomass at 28 days.

**Key words:** *Acacia angustissima*, *Acacia karoo*, *Gliricidia sepium*

## **Chronosequences of land clearance and simulation modelling of soil organic matter dynamics in Zimbabwean soils**

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The long-term dynamics of organic C and N were studied in soils under smallholder maize cultivation using cultivation chronosequences in Mafungabusi, Masvingo, Chivi and Chikwaka in order to determine the impact of land use change on soil organic matter. Studies were also done on a commercial farm chronosequence in the Chikwaka and Harare areas to provide a contrast in management. The C dynamics data for the different sites enabled the validation of the CENTURY model for the sites with different soil and climatic conditions. The source of soil organic matter in cultivated fields, either the original woodland vegetation (predominantly C3) or the subsequent maize crop (C4), was determined using the  $\delta^{13}$  signature of the soil organic matter. The Mafungabusi site was under Kalahari sands which had the lowest clay + silt content (5%) in the top 20 cm. The granite sands in Masvingo and Chivi had clay + silt contents ranging between 11 and 12%. The Chikwaka dolerite derived red clay soil had clay + silt values ranging between 48 and 50%. The initial C and N contents in the topsoil layer were highest in the Chikwaka clay soil (about 35 and 3 t ha<sup>-1</sup>, respectively), followed by the Masvingo and Chivi granitic sands (12 and 0.9 t ha<sup>-1</sup>) with the Mafungabusi Kalahari sand having the least (about 11 and 0.6 t ha<sup>-1</sup>). Rapid soil organic matter loss occurred within the initial 5 years of cultivation when land-use was changed from woodland to maize cultivation under smallholder management. The cultivation equilibrium organic C and N contents in topsoil were lowest in the Mafungabusi Kalahari sand (about 5.7 and 0.28 t ha<sup>-1</sup>) and the Masvingo and Chivi granitic sands (5.02 and 0.42 t ha<sup>-1</sup>). The C and N losses were slower and cultivation equilibrium organic C and N contents were largest in the Chikwaka red clay soil under commercial management. Describing the C and N decline trends by single exponential functions accounted for a large proportion of the variance in Ap1 horizon in Mafungabusi ( $R^2=0.67$  and  $0.72$ ). Masvingo and Chivi ( $R^2=0.69$  and  $0.83$ ). Chikwaka smallholder farming chronosequence ( $R^2=0.91$  and  $0.70$ ) and the Chikwaka commercial farming chronosequence ( $R^2=0.62$  and  $0.55$ ). Verification of the ability of the CENTURY model to simulate SOM dynamics across the study sites showed that even though the model output trends were generally consistent with the observed trends, there were significant differences between the measured values and the predicted values for the Mafungabusi and the chronosequences. The CENTURY model scenario analysis of management practices that may sustain soil organic matter showed low potential to build up of SOM at the Mafungabusi, Masvingo and Chivi sites as mineral N fertilisers and reduced tillage were predicted to have little impact on improving the soil organic matter contents at these sites. Large quantities of maize stover which are not achievable in these areas were predicted necessary to maintain SOM at the original woodland levels. Use of low quality cattle manure with high lignin contents was however predicted to have a strong impact on SOM build up in the sandy soils in Mafungabusi, Masvingo and Chivi.

**Key words:** Cattle manure, CENTURY model, organic carbon

## **Response of grain legumes to inoculation with exotic strains of *Rhizobium* in soils containing indigenous rhizobia in Zimbabwe**

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The response of bean (*Phaseolus vulgaris* L.) cv. Sugar bean, groundnut, (*Arachis hypogaea* L.) cv. Valencia R2, cowpea (*Vigna unguiculata* L.) cv. Vita 4 and soyabean (*Glycine max* L.) cv. Sable to inoculation with exotic strains of rhizobia in soils containing indigenous rhizobia as measured by nodulation, nodule occupancy, shoot dry matter and N content, grain and stover yields, grain and stover N contents and nitrogen uptake was investigated under both greenhouse and field conditions in 1987 and 1988. Indigenous rhizobial populations ranged from 0 to 69 g<sup>-1</sup> of soil at the study sites. Rhizobia nodulating groundnut and cowpea were the most prevalent, while those nodulating Phaseolus bean and soyabean were only detected at HRC. Each legume was inoculated with a mixture of approximately equal numbers of three effective exotic strains of rhizobia in soils, fertilised at 300 kg N ha<sup>-1</sup> or left uninoculated. Single occupancy of nodules was observed for strains TAL 102, 182 and 169 for soyabean, bean and both cowpea and groundnut, respectively. These appeared to be the most competitive strains. Multiple occupancy of nodules by the introduced strains was common among the legumes used. The following strains were only detected in doubly or triply- occupied nodules; TAL 377 and 379 for soyabean, TAL 1797 and 1383 for Phaseolus beans, TAL 658 and 209 for cowpea and TAL 1775 and 1000 for groundnut. They are presumably less competitive. For soyabean strains TAL 102 and 377 and groundnut strains TAL 169 and 1775, double occupancy was higher in the HRC soil. The recovery rate of inoculant rhizobia strains ranged from 0 to 66.6% in the greenhouse and from 0 to 55.6% in the field. Competitiveness, infectiveness and persistence of inoculant rhizobia strains as measured by nodule occupancy was higher with bean and soyabean compared to cowpea and groundnut strains in both field and greenhouse experiments. Dry matter yield and nodulation were enhanced by inoculation for bean and soyabean. Generally, inoculation enhanced both dry matter and nodulation at CAC, but not at HRC. Both soil type and growing season influenced the performance of introduced strains. Double occupancy of nodules by groundnut and soyabean strains was higher in the HRC than in the CAC. The observed differences in nodule occupancy patterns suggest that strain performance varied. Indigenous rhizobia in the soils studied presented a competition barrier to the establishment of introduced strains and this may have led to the observed lack of inoculation response. The potential for getting yield improvements by inoculating cowpea and groundnuts in these soils is very low. However, significant yield improvements are possible for bean and soyabean which had undetectable to low numbers of indigenous rhizobia.

**Key words:** Cowpea, groundnut, Phaseolus bean, soybean

## **Characterisation of Vesicular Arbuscular Mycorrhizal fungi and evaluation of the potential for co-inoculating with rhizobia in low fertility soils of Zimbabwe**

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The prevalence and population levels of Vesicular Arbuscular Mycorrhizal fungi (VAM) fungi in a range of field soil environments in Zimbabwe were determined. Mycorrhizal dependence (MD) of sorghum (*Sorghum bicolor*), soyabean (*Glycine max*) and cowpea (*Vigna unguiculata*) and the potential for yield improvement through inoculation with VAM and co-inoculating soyabean with VAM and rhizobia were investigated. The study showed that all the main VAM genera including *Acaulospora*, *Scutellospora*, *Gigaspora*, *Glomus*, *Sclerocystis* and *Entrophospora* were represented in the ten study sites. The relative abundance was *Glomus* > *Acaulospora* > *Scutellospora* > *Sclerocystis* > *Gigaspora* > *Entrophospora* at all sites except two where *Acaulospora* < *Scutellospora* and *Sclerocystis* > *Scutellospora* = *Acaulospora*. Different VAM genera occurred in constant proportions in the majority (eight out of ten) soils studied although population sizes varied with soil management. Spore numbers ranged from  $5.0 \times 10^4$  to  $52.5 \times 10^4$  per 100 g soil with numbers being generally higher in fallow compared to cultivated soils. Vesicular arbuscular fungal spore numbers were generally correlated with VAM infective propagules although spore counts tended to under-estimate VAM inoculum potential. Of the soil parameters measured, only organic carbon was significantly correlated ( $r = 0.62$ ,  $p < 0.01$ ) with numbers of VAM spores and infective propagules. Soybean, sorghum and cowpea were all found to be mycorrhizal dependent and inoculating them with VAM increased plant biomass and MD. Sorghum was more compatible with indigenous VAM. Mycorrhizal dependence decreased with increase in soil P. Inoculating sorghum and cowpea with VAM had the same impact on plant dry matter as adding  $50 \text{ kg P ha}^{-1}$ . There was a significant seed yield increase of soybean through inoculation with VAM and co-inoculation with VAM and rhizobia. Inoculation response to VAM was attained in a non-sterile soil typical of Zimbabwean communal areas. There is potential for exploitation of the two symbioses to enhance minimum input farming systems in the smallholder farming sector.

**Key words:** Cowpea, rhizobia, sorghum, soybean, spores

## **Socio-economic and agronomic evaluation of a soil management package for increased crop production by communal area farmers**

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Low soil fertility, variable rainfall and insufficient financial resources for inputs are some of the factors limiting maize production in communal areas (Cas) of Zimbabwe. The variation of rainfall led to the development of a flexible fertiliser management package to allow high yields in a high rainfall season and reduce risk of loss in a drought season. A soil management package (SMP) to combat these socio-economic and agronomic constraints was tested. The SMP comprised of: (i) preplant broadcast basal fertiliser (rates of phosphorus, potassium and sulphur based on nutrient requirements for optimum yields under average rainfall), (ii) multiple nitrogen applications with rates varied according to rainfall and yield potential at the same time

of application; (iii) post-emergence tied-ridging; and (iv) a loan for inputs. Farmer managed trials were carried out for three seasons in one high rainfall area (Natural region 2) four moderate rainfall areas (natural region 3) and two marginal rainfall areas (natural region 4). The Cas were all located on granitic sandy soils which were typical of Zimbabwean Cas. A baseline survey of the farmers conditions indicated that the SMP could be implemented by the majority of the farmers if credit for inputs was available and facilitation of timely delivery of inputs was done. The SMP was implemented by 35 selected CA farmers (5 in each area) on 0.5 – 0.75 ha plots. Inputs to implement the package were supplied on loan at interest based on the money market. The loan was to be repaid in the form of grain at the end of the season. The SMP plots were compared with control plots (ie. plots cultivated by implementing farmers using their normal soilmanagement practices) in terms of yields and profits. Average yields, profits and marginal rate of returns for the three years indicated that it was advisable and profitable to adopt the SMP in all natural regions (NRs), despite variabilities between seasons and among areas. Yield increases with adoption of SMP were 86, 59 and 60% for NR 2, 3 and 4, respectively. Profit increases for SMP plots were 121, 37 and 127% for NR 2, 3 and 4, respectively. Profits in NR 3 were low due to flooding and soil nutrient problems which could have been detected and avoided or solved. Profitability could have been improved in all NRs if N fertiliser rates were selected more carefully. Compared with farmer practices, the SMP yielded 54% higher in a drought year, 100% more in an average season, and 76% more in a wet season. The average profit increases obtained by using the SMP were 21, 60 and 253% for the dry, average and above average season respectively. Despite benefits of water harvesting, farmers were unwilling to implement post-emergence tied-ridging due to the extra labour and draught power involved. After the three year experimental period, SMP farmers repaid 93% of their loans. Although all the farmers were willing to adopt the technology, 29% of the farmers indicated that they were not willing to borrow money from formal lending institutions citing fear of penalty for failure to repay. Results from the three year experimental period indicated that apart from potassium in NR2, there was no significant decline in soil nutrient and pH levels, indicating that nutrient input approximately equaled removal by the crop. However, there may be need to include zinc and dolomitic lime as part of the SMP basal fertiliser to avoid long term zinc and magnesium deficiencies and ameliorate acidity.

**Key words:** Nitrogen, phosphorus, profitability, soil fertility

### **Geographic information systems as a tool for studying land use change and soil organic matter dynamics**

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Two communal area sites Mafungautsi (5 664 ha) and Chikwaka (199 ha), were investigated to document the change in land use and soil organic carbon stocks within 33 and 24 years, respectively. The two sites contrasted with respect to soils, climate and agricultural productivity. While Chikwaka lies on red clay soils and occurs in Natural region IIa with higher agricultural productivity, Mafungautsi is predominantly Kalahari sand and occurs in Natural Region IV with low agricultural productivity. Farmer surveys were also conducted in Mafungautsi, Chivi, Masvingo and Chikwaka communal areas. Most farmers from all the sites except Chikwaka, did not apply inorganic fertilisers, neither did they apply cattle manure and other organic soil amendments. While mineral fertiliser use in Chikwaka was common, it was not so with cattle

manure. Maize grain yields in Chivi, Masvingo and Mafungautsi were less than 1 t ha<sup>-1</sup> in most of the households; whereas most Chikwaka farmers got at least 2 t ha<sup>-1</sup> grain yield. IDRISI 32 and ArcView 3.2a Gis were used to measure the area of forest converted to arable land for these two sites. The consequent change taking place in the SOC stocks for the two sites was also estimated using the CENTURY (version 4.1) model and represented in ArcView. The Mafungautsi site recorded an increase of 2 741 ha in the arable land between 1972 and 1996. There was a 16% loss in the SOC contents of Mafungautsi from 24 to 20 t C ha<sup>-1</sup> within this period of time likely due to the change in land use. Chikwaka recorded a 43% loss in SOC from 47 to 27 t C ha<sup>-1</sup> for the 24 year period. The loss in SOC per ha was greater in the Chikwaka site although the equilibrium SOC contents were higher for the site than the Mafungautsi site. Various SOC management practices were simulated using the CENTURY (4.1) model in order to evaluate their potentials in building up SOC. The scenarios analysed were, conventional zero-input system typical of the communal areas, addition of N fertilisers at 50 kg and 150 kg N ha<sup>-1</sup>, addition of maize stover at 10 and 20 t ha<sup>-1</sup>, addition of cattle manure at 5 and 10 t ha<sup>-1</sup>, zero-till, natural fallow, and finally a maize-soybean rotation. For both sites, the addition of maize stover at 20 t ha<sup>-1</sup> led to the largest build up in SOC (35 and 40 t C ha<sup>-1</sup> for Mafungautsi and Chikwaka, respectively). The conventional zero input system was the least efficient practice with respect to SOC increase, giving 18 and 27 t C ha<sup>-1</sup> for Mafungautsi and Chikwaka, respectively. The differences in the ability to sequester carbon between the two sites were brought about largely by the differences in soil texture. The Chikwaka site with higher clay contents gave higher SOC contents for all scenarios although the patterns for the different practices were almost similar.

**Key words:** Arcview, CENTURY model, soil organic carbon

### **Effect of cotton-cowpea intercropping on crop yields and soil nutrient status under Zimbabwean rain-fed conditions**

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Intercropping of cotton and cowpea is one of the ways to improve food security and soil fertility while generating and maintaining cash income of the rural poor. A study was carried out to the effect of cotton-cowpea intercropping strategies on crop yields and soil nutrient status under rain-fed conditions. The study was carried out at Kadoma Cotton Research Institute (CRI), Ntini and Mukosi sites which are all in Kadoma District in Zimbabwe. Treatments were sole cotton, sole cowpea, and 2 rows of cotton alternating with 1 row of cowpea (2:1), 1 row of cotton alternating with 1 row of cowpea (1:1). The intercrops were either planted at the same (simultaneously), on cowpea was planted 4 weeks after cotton (4WAC). Cowpea suppressed cotton yields but the reduction was compensated for by the yield of cowpea and also the residual fertility from cowpea residues. The reduction in cotton yield was less when cowpea was planted 4 weeks after cotton and when the row configuration was 2:1 (cotton: cowpea). Cowpea grain yield across the sites was as follows, sole cowpea (1.6 t ha<sup>-1</sup>), 1:1 sim (1.1 t ha<sup>-1</sup>) 2:1 sim (0.7 t ha<sup>-1</sup>), 1:1 relay (0.8 t ha<sup>-1</sup>) and 2:1 relay (0.3 t ha<sup>-1</sup>). Cotton lint yield across the sites was as follows, sole cotton (2.0 t ha<sup>-1</sup>), 1:1 sim (0.7 t ha<sup>-1</sup>), 2:1 sim (1.2 t ha<sup>-1</sup>), 1:1 relay (1.5 t ha<sup>-1</sup>) and 2:1 relay (1.8 t ha<sup>-1</sup>). Comparable intercrops had higher cowpea grain yields in the simultaneous than in the relay intercrops but cotton lint yields were higher in relay than simultaneously planted intercrops. All the intercrops were productive as compared to the sole

crops with an average land equivalence ratio (LER) of 1.3 for both dry matter and grain yield across all sites. There was an increase in N fixation by cowpea in intercrops as compared to sole crops though the amount fixed was lower due to reduced plant population. Sole cowpea had N fixation of 73%, 2:1 simultaneous had 77% and 1:1 simultaneous had 83% while the total amount derived from N fixation was sole cowpea (104 kg N ha<sup>-1</sup>), 2:1 simultaneous (51 kg N ha<sup>-1</sup>) and 1:1 simultaneous (96 kg N ha<sup>-1</sup>). Sole cowpea and the intercrops contributed to positive N balances in the soil of 42.5 kg ha<sup>-1</sup> for sole cowpea, 25.7 kg ha<sup>-1</sup> for 2:1 simultaneous and 60.0 kg ha<sup>-1</sup> for 1:1 simultaneous. Cowpea fixed N which was transferred to the companion cotton crop was very low with 1:1 simultaneous recording 3.6% and 2:1 simultaneous 0.9%. Soil mineral N and plant available P generally increased after the intercrops with sole cowpea recording the highest and sole cotton the lowest and the intercrops recorded values were between those of sole cowpea and sole cotton. There was a slight change in pH and bases decreased but there was an increase in CEC. Microbial biomass C and N and particulate organic matter C and N all increased especially after intercrops as compared to sole crops. Nitrogen release from sole crop residue and mixtures was in the order 36.4 mg kg<sup>-1</sup> soil for cowpea residues, 33.4 mg kg<sup>-1</sup> for 30:70 mixture, 27.1 mg kg<sup>-1</sup> for 50:50 mixture, 21.6 mg kg<sup>-1</sup> for 70:30 mixture and 19.2 mg kg<sup>-1</sup> for cotton residues. The ratios given are for cotton: cowpea dry matter proportions obtained in the intercrops. The trend for C mineralisation was the reverse of N mineralisation and there was more C release from cotton residues. Grain yield after intercrops was substantial even without fertiliser (N) and was as follows, after sole cotton (1.1 t ha<sup>-1</sup>), sole cowpea (3.0 t ha<sup>-1</sup>), 1:1 intercrops (2.8 t ha<sup>-1</sup>) and 2:1 intercrops (2.5 t ha<sup>-1</sup>). Relay intercropping of cotton and cowpea is a good strategy to address issues of food security, income and soil fertility depletion. However, issues of cotton pesticides effect on humans and livestock need to be understood in order to provide the correct recommendations. Markets and marketing infrastructure for cowpea also need to be improved in order to increase adoption of this strategy by farmers.

**Key words:** Cotton-cowpea intercrops, residual fertility, phosphorus

## **Tolerance of selected maize and soyabean cultivars to soil acidity in Zimbabwe**

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Soil acidity is most important growth limiting factor, especially in the tropics and sub-tropics. Increased acidity in Zimbabwe's smallholder agricultural soils has been attributed to use of acidifying fertilisers without liming. Tolerant cultivars may allow for economic crop production under these conditions. The aim of this study was to develop a protocol for screening maize (*Zea mays* L.) and soyabean (*Glycine max* L.) cultivars for tolerance to Al and soil acidity and to assess response to lime by these cultivars on light and heavy soils. Soil samples (100) and soil amendment samples (80 cattle manure, 5 ash and compost and 5 termitaria) were sampled from Chendambuya smallholder farming area (SFA) to determine the fertility status and the extent of soil acidity. Five maize (SC 403, SC 517, CZH 00013, CZH 00017 and DK 8031) and 3 soyabean (Magoye, Safari and Solitaire) cultivars were screened for tolerance to Al in modified 20% Steinberg solution with 0, 4, 8, and 16 mg L<sup>-1</sup> Al<sup>3+</sup>. Maize (SC 403, SC 513, SC 517, PAN 413 and PHB 30G97), and soyabean (Magoye, Safari, Solitaire and Storm) cultivars were grown on limed and unlimed acid sandy and red clay soils in Chendambuya SFA and at Domboshawa

Training Centre for two seasons. Soils from Chendambuya had low pH (averaging 4.43) and only 19% were heavier soils comprising mainly red clay soils (21–40% clay) with over 4 times higher Ca and Mg compared to lighter textured sandy soils (0 - 5% clay). About 89% of the interviewed households applied cattle manure annually at an average of 5.3 t ha<sup>-1</sup>, while ash and compost were applied once in 3 - 4 years in low quantities and termitaria was only spread on the ground in the first year of ploughing to level the field. Manure was of poor quality (84% containing < 1.5% N) low liming value averaging 37%, and high soil content (averaging 56%). Aluminium reduced shoot dry matter yield (SDMY) for all maize cultivars (65, 84, 82, 74 and 77% reduction for SC403, SC 517, CZH00013, CZH00017 and DK8031 respectively at 16 mg L Al<sup>-1</sup>). Root response varied across cultivars and was thus more appropriate in screening maize for Al tolerance. The Al tolerance index (ATI) showed that CZH00017, CZH00013, SC403 and DK8031 were more tolerant to Al (ATI of 3.1, 3.4, 4.7 and 5.0 respectively) compared to SC517 (ATI of 1.0). Tolerant cultivars responded positively to low Al concentrations (4 mg L<sup>-1</sup>) and were more efficient in nutrient uptake and utilisation. At 4 mg l<sup>-1</sup>, Al resulted in an increase in soyabean root and shoot dry matter yield: Magoye and Safari (ATI of 5 and 2.51, respectively) were relatively more tolerant to Al compared to Solitaire (ATI of 1). Nutrient (P, Ca and Mg) translocation was reduced in all soyabean cultivars. Differential cultivar tolerance to Al was observed with both maize and soyabean. Lime reduced stover (up to 39%) and grain (up to 56%) yield on sandy sites except at Mudzengerere site with much lower Ca<sup>2+</sup> and K<sup>+</sup> contents (.70 and 0.09 cmol kg<sup>-1</sup> respectively) where yields were increased (up to 43 and 92% for stover and grain respectively). Up to 69% grain yield increases were realised on red soils. Cultivar PHB30G97 was recommended for acid soils as it yielded higher grain (6.18 and 6.67 t ha<sup>-1</sup>) than the Al tolerant SC403 (5.29 and 5.83 t ha<sup>-1</sup>) on acid red clay soil and on Domboshawa sandy soils respectively. Lime increased grain yield for Magoye and Safari in the two seasons and for Solitaire in the second season only. Soil acidity in Chendambuya SFA was high on both heavy and light textured soils. Cattle manure availability and quality was too low to have a fertilising and liming effect on soils. Aluminium tolerant cultivars can be selected for acid soil conditions using the ATI. Although liming is profitable on heavy textured soils, liming on light textured soils may result in reduced maize yields due to possible micronutrient deficiencies and nutrient imbalances in poorly buffered soil.

**Key words:** Aluminium, zinc, *Glycine max*, *Zea mays*

### **Composting of household waste for agricultural production in peri-urban farming systems of Zimbabwe**

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Rapid urbanisation has resulted in high population densities, declining waste management abilities and increasing food insecurity for large cities of most developing countries. Consequently, urban agriculture has increased in intensity. Improved utilisation of waste through composting offers a strategy for managing household waste and an opportunity to improve soil fertility. This study evaluated agricultural practices and socio-economic characteristics of selected peri-urban areas of Harare, Zimbabwe. Survey information was collected from peri-urban areas of Harare, Domboshawa and Porta Farm, by means of household interviewers. Most respondents from Porta Farm were unemployed, had limited access to land and relied on informal trade as a source of income. Furthermore, 80% of households at Porta

Farm earned less than US\$ 26 per month, while 80% of those at Domboshawa earned more than US\$ 26 per month in 1999. Most respondents from Domboshawa cultivated approximately 1 ha of land and relied on market gardening for a living. Epworth respondents showed the greatest dependency on the earned wage and 24% had no access to land. Both mineral and organic fertilisers including decomposed refuse were used extensively in the peri-urban areas studied. Seventy percent of household waste from peri-urban areas was compostable. Dry plant residues and fresh vegetable waste were the most dominant waste fractions. Waste generation rates were generally low averaging  $3.9 \text{ kg}^{-1} \text{ household}^{-1} \text{ week}^{-1}$  in the period November – December and  $9.8 \text{ kg}^{-1} \text{ household}^{-1} \text{ week}^{-1}$  during April - May 1999. The N content of the household waste ranged from 1.2-1.4% of dry weight. The C/N ratio averaged 30 and the lignin content ranged from 8.3-12.6%.

**Key words:** C/N ratio, household waste, fertilisers, vegetables

### **Tillage effect on soil organic matter fractions in long term maize trials in Zimbabwe**

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Long-term tillage effects on soil organic matter dynamics were evaluated for a Chromic Luvisol (red clay soil) and Arenic-Gleyic Luvisol (sandy soil) in Zimbabwe. The soils had been under conventional tillage, mulch ripping, clean ripping and tied ridging for at least nine years. Clay soil had about three times more soil organic matter than the sandy soil. Conventional tillage caused the highest organic C decline of 47 and 61% for red clay and sandy soils, respectively. The highest organic C content of (0.68%) in the sandy soil was under mulch ripping, while for the red clay soil tied ridging had the highest content of 2.04%. These values were, however, low when compared with the weedy fallow which was 1.13 and 2.79% total organic C soil for the sandy and red clay soils, respectively. Soils from the different tillage treatments were separated into five organic matter fractions. For effective soil organic matter fractionation, two soil dispersing agents were treated, sodium hexametaphosphate at two concentrations, 0.5 and 2% with soaking and non-soaking treatments and sodium resin bags. Complete dispersion was achieved with all dispersing agents for the sandy soil while for the red clay soil none of the dispersing agents used achieved complete dispersion because of aggregation in the red clay soil. Sodium resin bags solubilised organic matter causing a three-fold decrease in the amounts of coarse organic matter fractions for both soils. Pre-soaking of the soil, however, increased soil dispersion. Based on 0.5% sodium hexametaphosphate, all the tillage treatments reduced amounts of soil organic matter fractions, especially the coarse fractions. Conventional tillage reduced organic C in the coarse fractions by up to 70 and 84% for the red clay and sandy soils, respectively; and these were the highest declines for the tillage treatments. Clay size fractions were the most stable fractions as was shown by their small response to tillage with the least declines under tied ridging for the red clay and mulch ripping for the sandy soil. Most of the organic matter was associated with the finer fractions for the red clay soil while for the sandy soil the greater proportion of the organic matter was associated with the sandy fractions. Compared with the tillage treatments, coarse sand fractions of the weedy fallow had higher proportion of organic C to total organic matter of up to 16 and 25% for the red clay and the sandy soils, respectively. When expressed per unit of clay, the clay fraction of the sandy soil had up to  $100 \text{ mg C g}^{-1} \text{ clay}$  while for the red clay it had  $17 \text{ mg C g}^{-1} \text{ clay}$  suggesting differences

in mechanisms for organic matter stabilisation (physical/chemical) clay mineralogy for the two soils. Organic C and total N declined with depth up to about 20 cm for mulch ripping and the weedy fallow. An even distribution of organic C and N under conventional tillage was a result of mixing of soil from the upper and lower horizons. The decline in organic C and total N for mulch ripping and weedy fallow was more pronounced in the surface horizons from the 0-2 and 2-5 cm depths with about 20 and 50% decline respectively. In the upper 30 cm conventional tillage had lower organic C and total N than mulch ripping with both treatments having lower contents than the weedy fallow. At all depths, the coarse fractions had the least organic C and N contents while the clay fraction had the highest contents except for the coarse sand organic matter fraction of the weedy fallow which had the highest organic C and N in the surface horizon.

**Key words:** Clay, conventional tillage, sand, tie-ridging

### **Tillage and manure interactions under dryland cropping in semi-arid Zimbabwe**

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Rain-fed crop production systems in the semi-arid areas of Zimbabwe are characterised by low productivity due to low inherent fertility and low erratic and poorly distributed rainfall. The purpose of this study was to assess the interactions between different tillage practices and manure management techniques in relation to N and P uptake, crop yield and soil physical and chemical properties. Three tillage systems, namely, no-till (NT), summer plough (SP) and winter, followed by summer plough (WPSP) and three manure management systems; heap uncovered, and pit covered and heap covered, were used. Cattle manure used was applied at a rate of 4 t ha<sup>-1</sup> and had total N content ranging from 0.60 to 0.83%. The three tillage and cattle manure management systems had no significant ( $p>0.05$ ) effects on N and P uptake, sorghum yield, bulk density and soil moisture content over two seasons. Although there were no significant differences in the second season, biomass yield at vegetative stage, grain and stover yield were in the order WPSP>SP>NT. Manure chemical characteristics were affected by different curing methods, heap covered, heap uncovered and pit covered. Heap and pit covered cattle manure was of better quality after curing for three months. Covering manure reduced nitrogen losses. Nitrogen and OC losses ranged between 2 to 5 and 31 to 51 kg<sup>-1</sup>, respectively. Effects of soil type and manure type on N and P uptake and crop yield were evaluated in a pot experiment. Three soil types, sand, clay loam and black clay soils and two manure types, goat and cattle were used. The manure was of high quality, N=2.25% and had C/N ratio of 16 and 12 for goat and cattle, respectively. Sorghum biomass yield was in the order clay>sand>clay loam. Total mineralised N and P were high on clay followed by clay loam and sand had least. Nitrogen and phosphorus uptake was in the order sand>clay>clay loam. Calculated values of N and P uptake by sorghum ranged between 22 to 60 and 8 to 30%, respectively of total mineralised N and P. Goat manure amended pots had higher biomass yields than those with cattle manure.

**Key words:** Cattle, goat, nitrogen, pit-covered, plough

### **Balance and regime of soil moisture and its use by maize under rainfed conditions in Zimbabwe**

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Water usage by rainfed maize was investigated at three locations in Zimbabwe. Maize was planted on clay and sandy soils during early and late planting dates in the season. The gravimetric method was used to determine the agrohydrological properties (wilting point, field capacity and bulk density) of sandy and clay soils at 10 cm intervals down to a depth of 150 cm. Residual soil moisture was found to depend mainly on the quality of the previous season in the case of clay soils. There was no appreciable differences for sandy soils irrespective of the quality of the previous season. About 151 cm of rainfall were required to replenish a deficit of 50 mm in the 0 - 30 cm layer for clay soils. Maximum soil moisture extraction during the peak of the 1986/87 drought occurred between 30 cm and 60 cm depths. The dip in-the-soil moisture profiles associated with maximum extraction was not that pronounced during good seasons because of nearly uniform usage of soil moisture in the relevant depths. The Actual evapotranspiration (AE) was maximum during the tasseling to flowering phenological phases irrespective of the type of season. The study showed that there was less AE (488 mm) for early planted maize crop during a dry year, than for early planted maize during a wet year, i.e., AE (709 mm). These amounts refer to entire depths of 150 cm. Crop water requirements revealed that crop coefficients of the SR52 maize variety can attain a value of more than 1.0 during good rainfall seasons.

**Key words:** Actual evapotranspiration, residual soil moisture

### **Vegetation-soil relationships as aids to soil survey in semi-arid areas in Zimbabwe**

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The hypothesis that vegetation and woody species indicate soil type and land potential is very common in Zimbabwe and other similar countries. Research in vegetable-soil relationships to test this hypothesis is very limited in Zimbabwe. This study explores relationships between vegetation and soils along granite catenas found in semi-arid areas of Zimbabwe to establish the relationship between the two, so that they can be used as a land quality indicator for increased agricultural production in these areas. The study was conducted on granite in Mushandike Wildlife Sanctuary, Makoholi Research Station and Gutu Soti-Source Resettlement, all in Masvingo Province within agro-ecological region III and IV and in Maruta village found in Wedza Communal Land of Mashonaland East Province also in agro-ecological region III. Satellite image and air photo interpretations, vegetation classification and mapping together with vegetation measurements and soil profile assessments were used as data collection methods. Laboratory analyses of soils were done using standard procedures followed by AREX. Vegetation identification and measurements were done during the rainy season. There was a significant correlation ( $p < 0.05$ ) between species richness and soil characteristics that include drainage status ( $r = -0.53$ ); % clay in the B horizon ( $r = -0.28$ ); pH in the B horizon ( $r = -0.32$ ); CEC in the B horizon ( $r = 0.37$ ); Ca/Mg ratio in the A and B horizons ( $r = 0.85$  and  $r = 0.45$ ).

respectively); ESP in the B horizon ( $r=0.71$ ) and soil erosion intensity ( $r=-0.45$ ). There was no significant correlation between species richness and AWC of the soil. In addition, results also revealed that the differentiation of soils along the catena correspond with changes in vegetation physiognomy. Due to these vegetation and soil changes on the landscape, distinct patterns of land facets with different agricultural potential and management requirements could be identified and delineated on imagery and maps. The Detrended Correspondence Analysis (DCA) ordination analysis, however, showed that the major ecological gradients and the most important environmental factors that influence vegetation types and species composition along catena were related to soil moisture, drainage status, available soil nutrients, excess sodium salts and soil erosion intensity. The Canonical Correspondence Analysis (CCA) ordination analysis showed that the soil variables used in the analysis none of them except drainage status ( $p=0.03$ ) and erosion intensity ( $p=0.01$ ) were responsible for changes in the distribution and abundance of vegetation and species composition along the catena at  $p<0.05$  significance level.

**Key words:** Canonical Correspondence Analysis, Detrended Correspondence Analysis

### **Nitrogen leaching and recovery in a sandy soil amended with cattle manure and inorganic N under high rainfall conditions**

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The dynamics of mineral N in a sandy soil amended with aerobically composted solid cattle manure and inorganic N was studied under laboratory and field conditions. Nitrogen mineralisation/immobilisation patterns of 4 manures were determined using a laboratory incubation technique. Maize (*Zea mays* L.) was grown for 3 seasons in the field to determine N uptake patterns. Soil mineral N distribution in the soil profile was also determined in the same field plots by taking auger samples at given soil horizons during the three seasons. Nitrogen leaching losses and fertiliser N uptake efficiency by maize were measured using repacked lysimeters (free draining). In the incubation experiment, the manure with the lowest C/N ratio induced a short term (21 d) immobilisation of the applied N whereas the other higher C/N ratio manures induced no net changes in mineral N in the soil. Increasing rates of N depressed microbial activity in the manured soils. In the field, first season net N uptake from manure treatments was compared to N treatments. In the second season, N uptake was more depressed in the higher manure treatment compared with the low manure treatment and uptake from both manure treatments was still lower than from N treatments. Nitrogen uptake from manure plus N treatments was similar or higher compared with N only treatments. A comparison of net N uptake when manure and N were applied separately or in combination showed that separate application was superior but the difference was only significant ( $p<0.05$ ) in the first season for the low manure rate ( $12.5 \text{ t ha}^{-1}$ ) and N treatments. Mineral N (KCl extractable) was present at greatest concentrations at the beginning of the season and most of it was concentrated in the top soil. Nitrogen leaching measured in field lysimeters was higher in N fertiliser and manure plus N fertiliser treatments compared with the control and manure only treatments which represented both environments and economic concerns. Average leachate volumes ranged from 388 to 418  $\text{mm yr}^{-1}$  and high N concentrations (up to 37  $\text{mg L}^{-1}$ ) were recorded in the high N fertiliser ( $120 \text{ kg N ha}^{-1}$ ) and N fertiliser plus manure treatments. Fertiliser N use efficiency was 23.5 – 63.8% in the first season but was in the second season (19.2 – 34.3%). Fertiliser N

use efficiency generally increased with N fertiliser rate and was much higher when N fertiliser was applied in combination with manure compared with N fertiliser alone. The increased fertiliser N use efficiency in manure plus N fertiliser treatments could be related to the improvement in the soil physical (structure) and chemical (pH, exchangeable bases) environment associated with manure addition.

**Key words:** C/N, manure, mineralisation, *Zea mays*

### **Fate and impact of pesticidal proteins from *Bacillus thuringiensis* subspecies in selected tropical soils**

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Potential deleterious effects of pesticidal toxins from microorganisms and genetically engineered crops on non-target organisms have raised concerns for their environmental safety across the world. The fates and impact on soil micro-biota of *Bacillus thuringiensis* (Bt) proteins in a Vertisol, an Alfisol and two Oxisols were investigated through a series of adsorption and incubation experiments. The toxin from Bt suspension Tenebrionis (Btt) adsorbed in large quantities on clay fractions of the Vertisol (540 mg g<sup>-1</sup>), the Alfisol (200 mg g<sup>-1</sup>) and the Oxisol (110 mg g<sup>-1</sup>); and the adsorption could be attributed to clay mineralogy. Removal of sesquioxides increased the coefficient of determination of the Btt toxin on the Alfisol clay from 0.15 to 0.33 L g<sup>-1</sup> indicating that the presence of sesquioxides reduced adsorption of the proteins. Removal of organic matter reduced the amount of Btt toxin adsorbed on the Vertisol clay by 37% from 540 to 340 mg g<sup>-1</sup> but had no effect on toxin adsorption on Alfisol and Oxisol clays as a result of sesquioxides, which appeared to mask adsorption sites. Adsorption of the Btt toxin on clay fraction decreased as pH increased from pH 5.5 to pH 7.5 (isoelectric point of the toxin is pH 6.5) as a result of decreased electrostatic interactions between the negatively charged clay and the net-negatively charged toxin. Ionic strength increased the affinity of the toxin for the vertisol clay from a linear (C-type) to a high affinity (H-type) adsorption isotherm due to increased dispersion of the clay as a result of high Na<sup>+</sup> concentration. Amounts of Btt toxin adsorbed on whole soils were 19.4, 2.8 and 3.8 mg g<sup>-1</sup> for the Vertisol, Alfisol and Oxisol, respectively, and could be explained by clay contents of the soils. Microbial degradation of Btt toxin was reduced when adsorbed on clay fractions indicating that the toxin persist in the soils as a result of adsorption on soil particles. The toxin from Btt and crystal proteins from Btk and Bt subspecies Israelensis (Bti) showed no toxicity on soil bacteria, fungi and actinomycetes. In a Vertisol, bioactivity of the Bt subspecies Kurstaki (Btk) toxin, Cry1Ab, in Bt maize residues to 2<sup>nd</sup>-instar larvae of diamondback moth (*Plutella xylostella*) decreased rapidly from 76 to 30% mortality, in less than one week, and then remained constant over a 4 week incubation period. This observation indicated that the toxin could persist in the Vertisol for extended periods of time as a result of its adsorption to soil particles.

**Key words:** Alfisol, Btt-toxin, Oxisol, vertisol

## **Variability of the hydrology of semi-arid Zimbabwe and its implications on surface water resources**

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There are 170 communal lands totaling 163 500 km<sup>2</sup> or 42% of Zimbabwe. About 75% of these communal lands are in Natural Region IV and V that are semi-arid. Water development is, therefore, a key aspect in ensuring sustainable rural livelihoods in such areas where good yields are obtained two out of five years. Both groundwater and surface water resources provide water for domestic purposes and gardening during the dry season and during droughts. A study was carried out to investigate how the hydrology of catchments found in the semi-arid areas differ both spatially and temporarily and how it is affected by rainfall variability and land use changes and the implications on surface water resources. The temporal and spatial variability of rainfall and runoff of the Runde catchment in south-east Zimbabwe was studied using historical data. A second study compared the hydrology of Romwe and Mutangi micro-catchments that are located in the Runde catchment during two seasons representing a very wet and an average season. The effect of rainfall distribution and soil type was studied at Mutangi catchment and the implications on surface water resources were explored. A modelling approach was used to determine the effect of changing rainfall and land use changes and increased water abstraction on surface water resources. Rainfall varied from place to place within the Runde catchment. Cycles of variation of annual rainfall were observed and the long-term trends in runoff and surface water resources in dams reflect the effect of such rainfall cycles. Significant ( $p < 0.05$ ) correlation between rainfall and runoff were observed for stream gauging stations E2, E4, E49, E54, E112, E117 that were either in the Mutirikwi or Tokwe sub-catchment. No significant relationships between rainfall and runoff were observed in the upper and lower Runde sub-catchments. The hydrology of Mutangi and Romwe catchments were different in the two seasons because of different amounts of rainfall received. Romwe received (1430 mm) about double the rainfall that was received at Mutangi (755 mm) in the 1999/2000 season. The difference was only 140 mm in the following year when Romwe and Mutangi received 755 and 615 mm, respectively. Romwe generated about five times the runoff that was generated at Mutangi in the 1999/2000 season, which were 520 mm and 102 mm, respectively. The runoff was 82 mm and 69 mm in the 2000/2001 season at Romwe and Mutangi, respectively. Rainfall distribution and soil type had an effect on runoff generation at Mutangi. When there were a sequence of daily rainfall events that completely filled the storage capacity in both the soils and transitional soils, subsequent events produced very large runoff of more than 50% of the rainfall.

**Key words:** Ground water, runoff, spatial, surface water, temporal

## **Effect of tillage systems on seasonal water budgets and drainage of two Zimbabwean soils under maize**

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The effects of three animal powered tillage systems on seasonal water budgets were investigated on two research sites on a Ferrallitic red clay soil at the Institute of Agricultural

Engineering (IAE), and on a granitic sand soil at Domboshawa (DTC) in Zimbabwe. The objective was to evaluate the impact of tillage systems on soil water regimes, the potential yield benefits under different soil and weather conditions, and possible environmental consequences of their adoption by farmers. Two conservation tillage techniques, mulch ripping (MR) and no-till tied ridging (NTTR), were tested relative to the farmer practice, conventional mouldboard ploughing (CMP) under rain-fed, monoculture maize. Three broad and indirect physical methods of measuring and distinguishing drainage from evapotranspiration losses namely, (i) Darcy flux calculations, (ii) the simple water balance (SWB), and (iii) the zero flux plane (ZFP), were tested and developed. This was achieved from measurements of seasonal run-off, profile water contents,  $\theta$ , matric potentials,  $h$  and daily weather parameters at plot scale (300 and 1350 m<sup>2</sup> plots). *In situ* unsaturated hydraulic conductivity,  $k$  relationships with  $\theta$  and  $h$  and *in-situ* field capacity were also established. Significantly lower bulk densities ( $p < 0.001$ ) under MR compared to CMP (10 to 40 cm depths) were revealed; while NTTR generally induced the highest densities at IAE. CMP also exhibited significantly higher ( $p < 0.05$ ) surface bulk densities than MR and NTTR at DTC. On both sites, MR had significantly higher OC than CMP ( $p < 0.05$ ), while NTTR also induced higher OC which at DTC was significantly higher than CMP ( $p < 0.05$ ). When compared to virgin state by 1889, the decline in OC at IAE for CMP, MR and NTTR corresponded to 67, 53 and 47%, respectively; while that at DTC for the same treatments by 1997 corresponded to 61, 54 and 53%, respectively. Both cases experienced highest OC decline rates under CMP. The loosening effect of the plough under CMP was, therefore, temporary in nature and coupled to the rapid decline in organic carbon from virgin state contributed to poor soil fertility and increased surface run-off experienced by farmers. Overall, mean annual run-off lost for CMP, MR and NTTR were 22, 3 and 9% of seasonal rainfall at IAE compared to DTC where 20, 1 and 4% was also lost from the same treatments, respectively. At both stations, conservation tillage systems significantly ( $p < 0.01$ ) reduced run-off below that of CMP. On the other hand, double ring infiltrometer tests revealed insignificant differences between CMP and MR, while significantly higher infiltration rates ( $p < 0.05$ ) than CMP were observed under NTTR at DTC. On both sites, enhanced infiltration inferred from run-off under both MR and NTTR, respectively was influenced more by soil cover (40-60% crop residue cover) and surface configuration (ridges and cross ties) than by soil characteristics and  $\theta$ . On the contrary, the smooth surface, lack of residue cover (crop residues were removed) and high surface bulk densities (at DTC) accounted for the increased run-off from CMP. Using the soil water storage index (SWI), a parameter developed for comparing water storage between treatments, MR resulted in significantly better soil water storage ( $p < 0.05$ ) than CMP in the top 45 cm, corresponding to about 5% increase at IAE. Within the same zone, NTTR (mean of ridges and furrows) increased water storage by about 7% over CMP, while when assessed from the ridges, it resulted in 5% lower water storage than CMP. Under NTTR, planting crops on top of ridges reduced water availability to crops, while enhanced water storage was found in the furrows. Therefore, for marginal rainfall regions, planting in the furrows enhanced water availability to crops. Hence, for soils prone to waterlogging during excessive rainfall seasons, planting on top of ridges was more advantageous than in the furrows or on flat. On the other hand, MR generally improved water availability to crops compared to CMP and, thus, stabilised yields during both high and low rainfall cycles of seasons. The Darcy flux calculations underestimated and overestimated drainage between measurement intervals when based on  $k-\theta$  and  $k-h$  relationships, respectively, at IAE. Although the  $k-h$  relationships were an improvement over  $k-\theta$  ones, drainage was still poorly estimated. The improved SWB method modified to include a field derived drainage cut-off matric potential ( $h > 80$  cm) at measurement depth, proved quite an effective and practical tool for quantifying D and ET losses. The ZFP method was effective in one season (1997/98)

and insignificant differences were found between ET and D measured by either the improved SWB or ZFP. Overall, the improved SWB method was the most practical tool that could be applied to distinguish between ET and D losses. All the three methods failed to work at DTC because of gross violations of the assumption of one-dimensional flow. Accuracy of ET and D estimates depended heavily on measurement frequency and daily monitoring is recommended.

**Key words:** Darcy flux, organic carbon, water balance

### **Diagnosis and amendment of heavy metal toxicity and calcium/magnesium imbalance in Zimbabwean ultramafic soils**

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A study was undertaken to formulate interventions for large areas of infertile ultramafic soils associated with the Great Dyke of Zimbabwe, a significant feature some 530 km long. Maize was grown in sand culture with toxic additions of Ni and Cr and high levels of Mg relative to Ca to record symptoms and vegetative yield reduction. Maize was grown concurrently in 108 fertilised ultramafic soils in pots to compare growth and identify symptoms. Thereafter, most of the soils were amended with lime, gypsum and superphosphate to evaluate responses. The soils were stored for 8 years before applying amendments during, which time Cr toxicity developed in some soils. Subsequently, these amendments were compared in pot and field experiments at four specific sites. These amendments and sewage sludge were applied to a high Ni soil in pots also with Fe, B and Zn to evaluate vegetative responses. Manganese compounds were added to soils in several small experiments done with maize in pots. Leaf symptoms recorded for 108 soils were tip sticking and edge splitting negatively correlated with leaf Ca and leaf and soil Ca/Mg ratio interveinal chlorosis positively correlated with leaf and soil exchangeable Ni, discoloration and purpling positively correlated with leaf Cr and also stunting, distortion and edge scorch (necrosis). Chlorosis was most widely spread and was moderate on 43 percent and severe on 20% of soils associated with zero and 17% vegetative yield reduction, respectively. Moderate and severe edge splitting occurred on 19 and 12% of soils associated with 29 and 36% yield reduction, respectively. Thus splitting and low Ca had at least twice the effect of chlorosis and high Ni on yield reduction. In sand culture all symptoms occurred in maize and Ni and Cr treatments reduced yield but low Ca high Mg did not. Critical levels for leaf Ca, leaf and soil Ca/Mg ratio and leaf and soil exchangeable Ni were determined for onset of specific symptom and 90% of maximum yield both in the presence and absence of the other growth limiting components, leaf edge splitting occurred below a leaf Ca of 0.12%, leaf Ca/Mg ratio of 0.4 and soil Ca/Mg ratio of 0.6 in the presence of Ni and Cr. Yield was depressed by 10% at a leaf Ca of 0.1%, leaf Ca/Mg of 0.3 and soil Ca/Mg of 0.5 in the presence of Ni and Cr toxicity. In the absence of toxicity, corresponding values for leaf Ca, leaf and soil Ca/Mg ratio were 0.05%, 0.14 and 0.22. Chlorosis occurred above a leaf Ni of 13 mg kg<sup>-1</sup> and a soil exchangeable Ni of 27 mg kg<sup>-1</sup>. Yield was depressed by 10% above 12 mg kg<sup>-1</sup> Ni in the leaf and 27 mg kg<sup>-1</sup> Ni in the soil when Ca was low. Tolerance in the absence of Ca deficiency increased these threshold values to 30 mg kg<sup>-1</sup> Ni in the leaf and 40 mg kg<sup>-1</sup> Ni in the soil.

**Key words:** Chromium, gypsum, lime, maize, Nickel

## **Water management performance in smallholder irrigation schemes in Zimbabwe**

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The objective of the study was to produce a cross sectional performance assessment from a water management perspective of the formal smallholder irrigation schemes in Zimbabwe. A total of 12 schemes were selected and these consisted of AGRITEX and community managed schemes, which could either have a pump or gravity water conveyance system. Water delivery and rainfall data were collected daily during the 1990 summer and 1991 winter seasons. A total of 266 farmers in the selected schemes were interviewed on water management practices and problems. Some 107 AGRITEX personnel resident in all smallholder schemes as at December 1989 also provided data through a postal survey questionnaire. In all scheme types, water supply was adequate in both seasons. Reliability of supply was on average relatively poor ranging from 39% in pump schemes to 57% in AGRITEX schemes. The timeliness levels attained in AGRITEX and community schemes were less than 80% in both seasons. The relatively high levels in some individual schemes were achieved at the expense of high water wastage. The community and pump schemes performed better than AGRITEX and gravity schemes on the aspect of water wastage. The performance indices indicated poor reliability of supply and high water wastage. Such performance was confirmed by farmers through interviews. Major reasons for such performance were frequent pump breakdown poor maintenance of irrigation infrastructure, poor water management practices and uncontrolled priority for access to water between top-end and tail-end farmers. There is a high degree of cooperation among extension staff, farmer communities and individual farmers. This is a vital element for successful water management which facilitates and enhances farmer participation in making management decisions. Such is an important pre-requisite for coordinating and executing farm-level activities and should be maintained on existing schemes and promoted in future schemes. There were several technical and management problems that give rise to unreliable water supplies, for instance pump breakdowns, neglected maintenance of the canal and pump systems and inappropriate canal checks. Future design and construction of new schemes or the rehabilitation of existing ones should focus on providing means to ensure reliable and less wasteful water supply facilities.

**Key words:** Canals, pump schemes, waste water

## **Disappearance of atrazine in Zimbabwean soils**

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The disappearance of atrazine herbicide applied on a crop of maize on two soil types of Zimbabwe, a clay (5E.2) and a sand (5G.2) was measured during both wet and dry seasons. Both soil types showed that substantial amounts of atrazine residues are retained despite variations in rainfall. The residues that remained were found to cause phytotoxicity to soyabeans, resulting in reduced yield. The pH, clay content and organic matter of the soil were the main parameters found to enhance adsorption of atrazine to the soil. A combination of high clay content, greater than 10% and low pH (4.0) was shown to favour high atrazine adsorption by

the soil, while low clay content, less than 3% and high pH (7) retarded the process of adsorption. In soils treated with cattle manure, atrazine adsorption was found to be independent of pH, while soil pH increased with an increase in cattle manure applied to soil, atrazine adsorption also increased, indicating that organic matter influenced adsorption more than soil pH. Treating soil with cattle manure reduced atrazine phytotoxicity and increased soyabean yield.

**Key words:** Clay, cattle manure, organic matter, pH

### **Effect of soil erosion on nutrient loss from granite-derived sandy soils under different tillage systems in Zimbabwe**

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The rate and extent of soil erosion in Zimbabwe has been widely documented but not enough information has been generated on the impact of soil erosion on nutrient losses as well as soil fertility and productivity. Run-off, soil loss and yield were assessed under four tillage systems, namely bare fallow (BF), conventional tillage (CT), mulch ripping (MR) and tied ridging (TR). Clay, organic matter and nutrient losses due to erosion were quantified, where run-off, soil in suspension and sludge were treated as different entities. Nutrient losses as a result of leaching and plant uptake were also quantified, and compared to erosion losses. A soil nutrient balance was established. Conservation tillage systems (MR and TR) were more effective in conserving soil and water (ie. organic matter, clay and nutrients) compared to conventional tillage and bare fallow. Run-off ranged from 32% of total seasonal rainfall under BF, 12% under CT, 4% under MR and 3% under TR, while soil losses averaged 64 t ha<sup>-1</sup> under BF, 15 t ha<sup>-1</sup> under CT, 1.3 t ha<sup>-1</sup> under MR and 1.2 among t ha<sup>-1</sup> under TR. Treatments differed significantly at (p<0.001). Maize yields did not differ significantly. In all instances, the sediments had high enrichment ratios of organic matter and clay particles. However, this was more pronounced under the conservation tillage systems for which sediments were almost entirely suspended material. Enrichment ratios for clay and organic matter were; BF 1.5 and 2.6; CT 4.1 and 2.8; MR 13.5 and 4.6 and TR 15.5 and 3.4, respectively. The loss of clay and organic matter was higher under conventional tillage systems due to high soil losses and gave significant treatment differences at (p<0.01). Nutrient losses were dependent on the nutrient status in the soil the rate of erosion and the type of sediment fraction. The suspended material, which is easily splashed and more vulnerable to erosion proved to be the main carrier of clay, organic matter and nutrients making it the most detrimental to soil productivity. The nutrient enrichment ratios in suspended material were higher (N=6.2; P=5.9; K=6.8) compared to those in sludge (N=0.6, P=0.5, and K=0.5). The amounts of nutrient lost due to erosion were significantly lower under MR and TR compared to CT (p<0.001). The cost of replacing lost nutrients was significantly higher under conventional tillage than under conservation tillage systems (p<0.001), where BF lost Zimbabwe dollar (Z\$) 4 495, CT Z\$ 2 573, TR Z\$ 448 and MR 194 ha<sup>-1</sup> yr<sup>-1</sup> (Z\$ 55=US\$ 1) worth of nutrients. Drainage varied significantly (p<0.001) among the different treatments and seasons. The bare fallows recorded higher drainage than cropped treatments, while the conservation tillage systems recorded higher drainage (105 mm) than conventional tillage (79 mm). Leaching of nutrients also varied among different elements, where N and K recorded highest losses (0.86 and 2.0 kg ha<sup>-1</sup> K) compared to less than 50 g/ha recorded for P.

**Key words:** Conventional tillage, nutrient enrichment, run off

### **Influence of soil surface settling and sealing on the water, dynamics of three Zimbabwean topsoils**

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Deteriorating hydrologic conditions in Zimbabwe is to management practices which promote soil surface instabilities. Models developed to predict runoff and erosion in Zimbabwe have been largely empirical and have presented to some extent a reasonable understanding of the processes at work in different soils. This infiltration study aimed at determining aspects of soil hydrologic property change in three structurally different topsoils. It is divided into two phases, namely an investigation of settling and sealing processes. A combination of experimental observation and the predictions of mathematical models based on extensions of the Richards Water Flow and Horton Sealing Equations were used to gain insight into mechanisms active over small space/time frames. The soil matrix failure pattern of micro-granular clay was strongly influenced by both wetting rate and electrolyte dynamics. Soil subject to rapid wetting was found to be more sensitive to lowering electrolyte concentrations as infiltration progressed. Boundary conditions which promoted very high rates of wetting ( $>10 \text{ mm min}^{-1}$ ) resulted in infiltration trajectories which could best be explained by a delay in the wetting rate dependent 'infiltration throttle'. The time delay required to produce good infiltration predictions accorded well with observations on the slaking time (30-60 s) of aggregates rapidly immersed in water. The hydraulic conductivity of a fersiallitic clay loam ( $\text{ESP} < 1\%$ ) was found to respond strongly to electrolyte concentrations below  $1 \text{ me/dm}^{-3}$  (the electrical conductivity of inland rainfall in Zimbabwe has been measured at  $700 \text{ }\mu\text{S m}^{-1} \text{ H}^+$   $0.07 \text{ me dm}^{-3}$ ). An electrolyte flow model predicted that under conditions of natural rainfall, a dispersion gradient would be set up in this soil and this was confirmed with laboratory measurements of tensile strength and by field observations. Soil sealing investigations revealed that the micro-granular structure of the fersiallitic clay was stable to the impact of 3 mm drops below a critical potential of  $-1.6 \text{ kPa}$ . When this potential was exceeded, a particularly severe seal developed rapidly. Evidence emanating from the water and salt flow modeling work indicated that the amount of information which had to be processed in order to obtain a given level of predictive precision was directly related to the structural complexity of the soil. The influence of salt and/or water dynamics on soil matrix stability and, hence, on infiltration trajectories dependent on the soil and boundary conditions applied. Indeed processes to which the water flow model was particularly sensitive. Slaking time, directly threatened deterministic models based on the Richards Equation and physically measured parameters.

**Key words:** Electrical conductivity, hydraulic, models, infiltration

### **Evaluation of the agronomic potential and effectiveness of Zimbabwe Dorowa phosphate rock - based phosphate fertiliser materials**

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This study explored the agronomic potential and effectiveness of Dorowa phosphate rock (DPR)-based fertiliser materials under laboratory and field studies to examine the effects of aging on water soluble phosphate (WSP) + citric acid soluble phosphate (CSP) of DPR-based

pelletised phosphate blends (PPBs) and compacted phosphate blends (CPBs). Additional treatments included compaction of the blends with castor cake (CC) or manure (M). The WSP in blends decreased while, CSP increased as a result of aging for up to 50 days after manufacture. The decrease in WSP was inversely related to the increase in CSP. The CPBs had higher WSP and CSP than corresponding PPBs. Castor cake (CC) CPBs had higher WSP and CSP than manure (M) CPBs at 50 days of aging. The CSP and WSP levels for blends were intermediate between those of pure DPK and triple superphosphate (TSP), at similar levels of total P. Dissolution of DPR-based P fertiliser materials was greatly enhanced by pelletising or composting DPR with TSP as measured by P and Ca release. CPBs released more P and Ca compared with corresponding PPBs. Compacting DPK and TSP with organic materials enhanced the dissolution of the DPR-based P fertiliser materials. Use of castor cake (CC) enhanced the dissolution more than manure (M) in the compacted fertiliser materials. Solubility of DPR blends was enhanced more by the red clay soil probably because of its higher P adsorption and  $\text{Ca}^{2+}$  adsorption (ie., CEC) as compared with the sandy soil. Modelling P and Ca release followed the order: simplified-Elovich > power-function > parabolic diffusion. Phosphate release at 8 days incubation in an open incubation system was much higher than P release at 49 days in a closed incubation system due to continual removal of P in an open system compared to closed system. The P and Ca release from the DPR-based P fertiliser materials in an open incubation system was best described by the parabolic-diffusion model followed by the power-function model and least by the simplified-Elovich model.

**Key words:** Calcium, compaction, pelletisation, P solubility, TSP

### **Effect of seed priming, soil moisture and aggregate size on cotton and maize crop growth in semi-arid Zimbabwe**

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Seed priming has been identified as one of the methods that improves crop establishment in the semi-arid tropics, but the physiological basis for its benefits are not well understood. Priming might not induce physiological advantages, but benefits could be the result of interactions with soil physical conditions. To explain these issues, the following experiments were carried out: (i) effect of sowing under deteriorating seedbed soil moisture and seed priming on emergence and growth of maize; (ii) effect of seed priming, water potential, seed size and variety on cotton (*Gossypium hirsutum* L.) and maize (*Zea mays* L.) germination; (iii) effect of seed priming, soil water potential and soil aggregate size on emergence of cotton and maize, and (iv) effect of simulated sowing rainfall, tillage and seed priming on maize and cotton emergence and growth. Primed and non-primed maize seeds were planted over a period of eight successive days and emergence, growth and yield of primed and non-primed seedlings that emerged on the same day was monitored. Priming significantly improved emergence ( $p < 0.01$ ) by 11% and lowered time to 50% emergence by a day. There were significant effects of priming on growth, time to flowering and maturity and yield of primed and non-primed plants that had emerged on the same day. Interacting seed priming, water potential and variety of cotton resulted in improved emergence with priming at lower potentials (-100 and -200 *versus* 0 and -10 kPa). Varieties responded differently to low water potential, variety CY889 was more affected by low water potentials than SZ93-14, with germination of 30 and 60%, respectively at -200 kPa. Primed cotton seed achieved the optimal 70% germination at -200 kPa, while the non-primed

achieved it at -100 kPa. Germination in cotton was more uniform and faster for primed seed. In maize, there was significant ( $p < 0.01$ ) water potential x seed size and water potential x seed treatment interactions. Small seeds had better emergence at lower water potentials compared to large seeds. Germination percent for small seeds was 50% while the average for medium and large seeds was 35% at -500 kPa. Primed maize seed achieved 72% germination at -200 kPa, while germination for non-primed maize seed was 50% at the same water potential. Priming improved emergence ( $>70\%$ ) at low water potentials (-10 kPa and -50 kPa *versus* 100 kPa in smaller aggregates (1-2 mm < 1 mm and mixed versus 4.75-16 mm and 2-4.75 mm) in cotton. The decrease in emergence and seedling vigour as water potential was lowered was less for primed seed compared to non-primed seed, and also less for small aggregate size distributions in cotton. In maize, an identical trend was observed. However, primed maize seed gave optimal emergence (70%) in all aggregates with diameter less than 16 mm at an initial water potential of -10 kPa. Priming benefits on emergence are cancelled out where soil water potential (greater or equal to -10 kPa) and soil aggregate sizes (mixture of aggregates <16 mm) are not limiting.

**Key words:** *Gossypium hirsutum*, seed emergence, *Zea mays*

### **Soil organic matter dynamics in natural and disturbed environments in Zimbabwe**

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Most of the agricultural systems in Zimbabwe and other parts of Southern Africa are derived from Miombo dominated savanna ecosystems. Poor soil fertility and land degradation due to improper land use systems, such as poor agronomic practices, over-grazing and settlement patterns in newly opened natural savanna woodlands have often been linked to declining soil organic matter (SOM). This study investigated the impact of a range of land use practices on SOM dynamics, with a view to developing strategies for minimising SOM loss and soil degradation. The effect of grazing, managed pastures, cropping systems, land clearance and settlement, on SOM build up, maintenance and loss, on a loamy sand were investigated under simulated land management practices at Marondera in Zimbabwe. Litter biomass accumulation was influenced by rainfall and soil moisture availability. Total annual litter fall ranged between 283 and 507 g m<sup>2</sup> yr<sup>-1</sup>, of which leaf and leaflet litter constituted 34-44%. High litter fall was recorded during the period May to September (dry season) and was highly variable between years. Litter N concentrations varied seasonally, especially those of the leaflet and fragmented litter fractions. Both C and N mineralisation of the Miombo litter were influenced by litter quality. High quality litters from seed and flower parts did not significantly ( $p < 0.05$ ) contribute to the SOM and N pools. Fractionation of litter into different C fractions gave good estimates of potential C mineralisation patterns. Initial decomposable C (ie., total C minus (lignin C + polyphenol C + cellulose C)) was highly correlated with C mineralisation ( $r = 0.88$ ). Total litter N content was the best predictor for N mineralisation ( $R^2 = 0.86$ ). Combinations of different quality parameters gave estimates of potential C and N mineralisation than single parameters. Land management types affected the quality and quantity of native SOM by altering the nature of the above ground organic inputs, nutrient status and soil moisture content. Seasonal inputs of litter significantly increased mineralisable C and N fractions of native SOM in the natural woodland and tree litter inputs, illustrating the dependence of C and N dynamics on short term organic inputs. Total C content of soils under the tree litter inputs treatment increased

by 18% in the top 10 cm. Removal of above ground inputs resulted in a decline of 14-20% for total organic C and 23-36% for total N in the top 10 cm of the soil profile over the five year period. Microbial biomass C and N also declined by over 30% while POM declined by 40%.

**Key words:** Carbon, litter biomass, Miombo, nitrogen

### **Influence of water on the nitrogen use efficiency of crops on Zimbabwean granite derived soil**

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This study aimed at determining the effect of water on leaching losses of nitrogen from cropped soil and the impact of such leaching on the efficiency of nitrogen use by crops. Two sets of 1.2 m deep lysimeters were used to measure N leaching. Eight lysimeters of 1 m diameter were paired in four field plots that were used to study mineral N dynamics. Maize (summer crop) and wheat (winter crop) were grown in these lysimeters and plots. Four lysimeters that had previously received ammonium nitrate received isotopic  $^{15}\text{N}$  in ammonium sulphate. In 1991, the labeled aboveground parts of maize from those lysimeters were ground and incorporated into other four lysimeters that received manure. The SOIL-SOILN models, which simulate soil nitrogen dynamics were tested on N measurements made in soil and leachate. Lysimeters that received manure mostly had large volume of leachate than those that received fertiliser-N. The largest seasonal nitrate loads ( $17\text{-}39 \text{ kg N ha}^{-1}$ ) from the large lysimeters were obtained in summer 1989/90. Although no N was added to the 1990 wheat, more nitrate was leached ( $3.7\text{-}18.6 \text{ kg N ha}^{-1}$ ) than in summer 1990/91 in the F ( $0.6$  and  $9.3 \text{ kg N ha}^{-1}$ ) and M ( $0.3$  and  $3.0 \text{ kg N ha}^{-1}$ ) lysimeters of the W1 and W2 treatments. Mineral-N in soil increased in all plots during winter 1990, suggesting that the incorporated maize residues were releasing N through decomposition and mineralisation. Twenty seven percent of fertiliser- $^{15}\text{N}$  was recovered in aboveground maize parts of both water treatments, while not more than 0.25% was leached from the W1 and the W2 lysimeters. At most, fertiliser- $^{15}\text{N}$  accounted for 1.8% of the leached nitrate. Although all lysimeters received the same amount of water, leached loads of mineral-N were smaller ( $1.4\text{-}5.5 \text{ kg N ha}^{-1}$ ) in the previously W1 than in the previously W2 ( $3.1\text{-}8.1 \text{ kg N ha}^{-1}$ ) lysimeters. When all lysimeters received  $100 \text{ kg ha}^{-1}$  fertiliser-N in 1992, N loads were smaller from the previously M lysimeters ( $0.1\text{-}0.8 \text{ kg N ha}^{-1}$ ) than in those on the F treatment ( $0.2\text{-}2.7 \text{ kg N ha}^{-1}$ ). Larger water inputs often increased plant growth and decreased leaching. Larger inputs of water and fertiliser-N increased N turnover, N uptake and  $^{15}\text{N}$ -recovery from the labeled maize material incorporated in potted soil. The SOIL model underestimated the discharge of leachate, but SOILN overestimated nitrate concentrations after fertilisation such that simulated nitrate loads at the end of the season were comparable to measurements.

**Key words:**  $^{15}\text{N}$ , lysimeter, maize, soil N, wheat

### **Effect of crop sequencing on effectiveness of Dorowa phosphate rock source of phosphorus in Zimbabwe**

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Declining soil fertility remains the fundamental cause for the reduction in per *capita* food production in Sub-Saharan Africa, N and P being the most limiting nutrient elements. In Zimbabwe, there is a decline in soil fertility as farmers take out more nutrients than they apply. While soil N status can be improved through several means such as biological fixation, P has to be added. An experiment was conducted in the greenhouse and at two field sites in Zimbabwe. Treatments consisted of five P fertiliser rates (0, 40, 80, kg ha<sup>-1</sup> P<sub>2</sub>O<sub>5</sub> as DPR and 80 kg ha<sup>-1</sup> P<sub>2</sub>O<sub>5</sub> as DSP) and five initial crops (cow pea, groundnut, pigeon pea, sugar bean and rapeseed). There was an increase in soil available P<sub>2</sub>O<sub>5</sub> with increase in DPR rate. Available P<sub>2</sub>O<sub>5</sub> after harvest of the initial crops was higher where P had been applied as DSP compared to DPR. The amount of available P<sub>2</sub>O<sub>5</sub> after the different initial crops had been harvested varied significantly. Rhizosphere pH after the crops was lower where the legumes had been grown compared with rapeseed. Maize biomass was higher where P had been applied as DPR than with DSP. Maize biomass showed higher RAE of DPR with respect to DSP compared to results on soil available P<sub>2</sub>O<sub>5</sub> after the initial crops were harvested. There was no maize grain yield response to the different P fertiliser rates. The interaction of DPR rates and different initial crops resulted in significant differences in maize biomass yield. Maize biomass yield was higher where groundnuts had been previously grown in combination with DPR compared with the other initial crops.

**Key words:** Cowpea, groundnut, nitrogen, pigeonpea, rapeseed

### **Effects of inorganic soil fertility inputs and soil type on establishment and growth of *Moringa oleifera* in Zimbabwe**

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*Moringa (Moringa oleifera)* is gaining wide acceptance in Africa as an agroforestry plant and vegetable, yet the nutrient requirements for its establishment under the depleted smallholder sandy soils in Zimbabwe is not known. A study was carried out to investigate the effects of soil pH, nitrogen, phosphorus, manure and soil type, on initial establishment and growth of *M. oleifera* at Africa University and Marange in Zimbabwe. Three levels of agricultural lime (0, 4000 and 8000 kg ha<sup>-1</sup>), four rates of nitrogen (0, 200, 400 and 800 kg N ha<sup>-1</sup>) and four levels of phosphorus (0, 100, 200 and 400 kg ha<sup>-1</sup> P<sub>2</sub>O<sub>5</sub>) were combined factorially. In the second study, greenhouse experiments were carried out on four soil types, namely, sandy, sandy loam, clay loam and clay soils. Manure was applied to the soils at levels of 0, 10, 20 and 40%, respectively, as a ratio to soil mass. Plant height, number of branches, basal stem diameter, root, shoot and total dry biomass significantly ( $p < 0.05$ ) increased with increase in manure, lime, N and P rates. Root dry matter increased by 17, 33.9 and 56%, respectively compared to control after application of 100, 200 and 400 kg ha<sup>-1</sup> P<sub>2</sub>O<sub>5</sub>. Application of 4000 kg ha<sup>-1</sup> lime and 276 kg N ha<sup>-1</sup> resulted in a 153% increase in plant height. An increase of 173% in moringa height compared to the control, was recorded where 40% manure was applied. Manure increased basal stem diameter, height ( $p < 0.001$ ) and plant tissue calcium concentration. Clay loam soils were the best soils to

grow moringa. A manure rate of 40% was the best for establishment and growth of moringa. Soil pH of 6.2 was observed to be optimum.

**Key words:** Lime, manure, *Moringa oleifera*, nitrogen, phosphorus

### **Closing the soil nutrient loop between rural and urban centres through composting municipal organic wastes with Dorowa phosphate rock in Zimbabwe**

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Municipalities generate large quantities of organic wastes, which are costly to dispose of and yet have potential use as organic inputs for farms. A study was carried out to (i) investigate the nature, quantities and nutrient compositions of organic wastes generated by the city of Mutare, (ii) determine the P benefits of composting sewage sludge, wood waste and vegetable vending waste with DPR and sulphur, and (iii) to determine the effect of municipal organic wastes composted with Dorowa phosphate rock (DPR) and sulphur on the performance of waste of groundnuts (*Arachis hypogea* L.) and maize (*Zea mays* L.). Three major organic categories were found, namely; wood processing waste (WW), vegetable vending waste (VW) and sewage sludge (SL). Sewage sludge, VW and WW contained 0.11, 0.08 and 0.01 P<sub>2</sub>O<sub>5</sub> and 1.5, 0.7 and 0.7% N, respectively. Sewage sludge and VW had nutrient contents comparable with those of cattle manure from the smallholder farms. The total amounts of major nutrients (N and P) in the waste were enough to fertilise at least 234 hectares of maize using Zimbabwean fertiliser recommendations. Organic waste x DPR interactions significantly increased available P (p<0.001). Organic waste type significantly affected available P (p<0.001). DPR (p>0.05) and sulphur (p>0.05) did not significantly affect available P. Phosphorus immobilisation by WW was observed during composting from 28 to 56 days. Application of beneficiated SL improved groundnut dry matter, but did not significantly improve maize dry matter. Soil residual P was significantly (p<0.05) higher where municipal organic amendments were applied than with other soil amendments after growing groundnuts as a test crop. Only beneficiated SL left behind enough soil P (>30 ppm) after growing maize. Beneficiation improved groundnut leaf P, but not beneficial in maize. Beneficiating SL improved groundnut yield. No maize benefit above non-beneficiated composts was observed with all the three beneficiated wastes. The use of beneficiated composts produced comparable yields with other inorganic amendments, improved plant tissue P and residual P.

**Key words:** Groundnut, maize, sewage sludge, wood waste

### **Use of Dorowa phosphate rock to improve soil fertility in smallholder maize and groundnut production systems in Zimbabwe**

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The benefits of composting Dorowa phosphate rock (DPR) with various legumes and grain crop residues has not been adequately researched, despite the potential benefits that could be

realised. This research sought to find the effect of composting DPR with organic residues on P availability and yields of maize and groundnuts evaluated. In a greenhouse experiment, five DPR rates were used (10, 40, 80, 120, 160 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>). The rates were combined with each of the following organic matter residues; groundnut, soyabean, *Calliandra calothyrsus*, dry grain amaranthus and fresh grain amaranthus, *Leucana leucocephala*, *Sesbania sesban* and also without organic residue as a control. The organic materials were applied at 5 t ha<sup>-1</sup>. The DPR organic matter ratios in the composts were 0.22, 7.1, 22. In a field experiment four DPR rates were used (0, 40, 80, 160 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>). The rates were combined with each of the following organic matter residues; groundnut, soyabean, *C. calothyrsus*, dry amaranthus, and fresh amaranthus inflorescence stover left after threshing and also without organic residue as a control. The organic materials were applied at 4 t ha<sup>-1</sup>. The DPR organic matter ratios were 0:16, 0.088: 16 0.177. Increase in DPR resulted in increased dry matter and grain yield of maize and groundnuts. Composting DPR resulted in higher dry matter and grain yields for both maize and groundnuts, compared to uncomposted DPR. The response was greater in maize than in groundnuts. DPR composted in *S. sesban* and dry grain amaranthus gave higher maize dry matter yields than that composted in other residues. DPR composted with dry grain amaranthus and *C. calothyrsus* gave the highest groundnut dry matter and grain yield, respectively. The highest yields in both maize and groundnuts were obtained with DPR composted at the rate of 160 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>. Composted DPR had higher relative agronomic effectiveness (RAE) than uncomposted DPR. DPR composted with *S. sesban* had the highest RAE (60%) while uncomposted DPR at the same rate had the lowest RAE (32%) for maize dry matter yield.

**Key words:** Agronomic effectiveness, *Amaranthus*, *calliandra*, *leucana*, soybean

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## **Petrology and geochemistry of syenite intrusions in the Eastern Province of Zambia**

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Syenitic rocks in eastern Zambia are represented by both oversaturated quartz bearing types and undersaturated nepheline-sodalite varieties. The Sinda syenite intrusions are oversaturated potassic syenites, which form a petrogenetically related N-S trending string of intrusions at the eastern margin of the Sinda batholiths. The northern most Lusandwa intrusion is a composite diaper covering some 70 km<sup>2</sup>, while the smaller Mayira, Seya, Pule and Tantha intrusions to the south are increasingly sill-like reflecting a strong structural control to their emplacement. Petrographically, the syenites range from mafic pyroxene syenite through hornblende syenites to leucosyenites in the Lusandwa and Mayira intrusions are homogeneous hornblende syenites. The intrusions show systematic variations in chemistry from the mafic syenites to the felsic syenites, which are attributed to fractional crystallisation. The Lusandwa and Mayira intrusions define an alkaline trend representing fractional crystallisation of a mafic alkaline syenite magma, while the Pule, Tantha and Seya intrusions deviate from this trend towards calc-alkaline compositions, reflecting a change in the crystallising assemblage induced by changes in the physical conditions during crystallisation. The apatite rich bodies within the Mayira intrusion, which are under investigation as phosphate ore have a mineralogy and mineral chemistry which indicate an origin as cumulates, with subsequent emplacement at a late stage of solidification. The Lunkhwakwa intrusion I in the Chipata area is an over-saturated potassic syenite, which ranges in petrography from a mafic pyroxene syenite to leucosyenite, while the Bandawe intrusion in the south comprises of a homogeneous sodi-potassic nepheline syenite. The two intrusions also exhibit systematic chemical variations, which are attributed to fractional crystallisation. The chemistry of the Bandawe syenite is significantly different from that of the Lunkhwakwa syenite, suggesting that two intrusions originated from two different magmas. The Bandawe magma is considered to be a derivative of an alkaline magma of mantle origin whilst the Lunkhwakwa magma has a partly crustal origin. The Mivula Hill intrusion is an undersaturated layered intrusion, which petrographically is a nepheline-sodalite syenite. Chemically, the intrusion is miaskitic and peralkaline. The chemical variation within the exposed part of the intrusion is attributed to both fractional crystallisation and crystalliquid mixing processes with the latter predominating. Rb-Sr isotope data have yielded an isochron with an age of  $1340 \pm 16$  Ma and an initial Sr isotopic ratio of  $0.7028 \pm 0.0001$ . The Sr ratio suggests mantle origin for magma, while the age is somewhat controversial and suggests the intrusion to have taken place in the early stages of the Kibaran orogeny.

**Key words:** Alkaline, fractional crystallisation, pyroxene, Quartz

## **Petrology of the sulphide deposits and host rocks of the Lutala Hills in the Nyimba area, eastern Zambia**

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The Lutala Hills prospect is a massive sulphide mineral occurrence associated with amphibolites and gneisses which underlie most of the Nyimba area. It is situated in the Irumide fold belt and

the host rocks form part of the basement rocks of proterozoic age in eastern Zambia. Two orogenic cycles, the Kibaran (1600-1100 Ma), and the Mozambican (700-400 Ma) have deformed and metamorphosed the rocks up to upper amphibolites and greenschist facies, respectively. The main massive sulphide body consists of pyrite and pyrrhotite, with associated magnetite and minor sphalerite, chalcopyrite, ilmenite, melnikovite-pyrite and trace rutile, marcasite, covellite, digenite, hematite and goethite. Much of the magnetite associated with the massive sulphides formed through the desulphurisation of pyrite during metamorphism. Petrological study of amphibolites has shown that basic volcanism of within plate basalts erupted in an intra-cratonic or epicontinental environment, resulted in the formation of basalts and andesites later metamorphosed to amphibolites. The sedimentation that accompanied this volcanism was predominantly of clastic greywacke sequences later metamorphosed to gneissic rocks. The highly sodic nature of the paragneisses indicates that a continental source area such as an archaean craton composed of tonalite-trondhjemite suites, provided the detritus. The base-metal mineralisation associated with the massive sulphides is of a low-grade Zn-Cu type with the best values of 0.78 and 0.20% Cu. The sulphide mineralisation precipitated from hydrothermal solutions of volcanic origin during the waning phases of volcanism and resulted in a volcanogenic Besshi-type of massive sulphide deposit. Exploration programmes in the area for economic mineralisation should be guided by the close relationship shown by Cu to the amphibolites and by the associated iron formations that occur in rock succession. In addition, a structural control by major linear faults also influences the localisation of the mineralisation.

**Key words:** Amphibolites, hematite, gneisses, orogenic cycles, pyrite

### **Geochemistry and metamorphism of calc-silicate rocks, marble and amphibolites in Zambezi Belt, Southern Zambia**

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Calc-silicate rocks and marble of Katanga age underlie a significant segment of the Zambezi belt in Southern Province of Zambia. The calc-silicate rocks are represented by spectacularly banded calc-silicate gneiss, calc-silicate schists, massive calc-silicate rocks and a few mottled varieties. The marbles are uniformly calcite and dolomite marbles. In the Mapanza area, minor amphibolites are sporadically distributed as lenticular bodies, bands and boudins within the marbles and calc-silicate rocks. The rocks were deformed and metamorphosed to amphibolites facies and later partly retrogressed to greenschist facies during Pan-African tectonothermal events. Amphibolite facies assemblages in the calc-silicate rocks include biotite scapolite+quartz, calcite+diopside+grossularite+sphene and quartz, plagioclase+calcite+quartz+plagioclase+diopside+calcite+sphene. Those in the marbles include dolomite, tremolite, calcite, biotite, scapolite, dolomite and diopside. The amphibolites are of basic igneous origin with a possible minor sedimentary component for the amphibolites boudins and bands. Their mineralogy is largely influenced by the bulk composition, with garnet occurring only in amphibolites with  $Fe/(Fe, Mg) > 0.5$ . Geochemical data, Niggli parameters and plots of inter-element correlations for the calc-silicate rocks and marbles are presented. These support the conclusion that during metamorphism, the major elements were not significantly mobilised. Instead the variation in bulk chemical composition of the rocks and the resulting variations in equilibrium metamorphic mineral assemblages are best explained in terms of original variations

in the proportions of clays and other detrital phases intermixed with carbonate during deposition. Geothermobarometry is applied for the first time in this part of the Zambezi belt. Composition of coexisting biotite and garnet in the amphibolites yield temperatures of 630-660 °C, and composition of coexisting plagioclase and hornblende in the amphibolites yield temperatures of 560-630 °C and pressures of 5-6 Kbars for the peak of metamorphism. These values which are in accord with intermediate pressure (Barrovian type) amphibolites facies metamorphism are consistent with the phase assemblages in the calc-silicate rocks, marbles and amphibolites based on published experimental data. Compositions of calcite coexisting with dolomite in the marbles yield maximum temperatures of 490-500 °C, apparently reflecting re-equilibration following the peak of metamorphism.

**Key words:** Amphibole, Calc-silicate, dolomite, quartz

### **Geology, geochemistry and exploration of igneous phosphates Northwest of Mumbwa Central Province of Zambia**

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The syenites and quartz feldspar porphyries of the Mumbwa district in Zambia, occur as satellite bodies at the north-east margin of the hook granite massif; large batholiths dated 456 Ma, and intrude the pre-cambrian Katanga metasediments. The composition of syenite rocks varies from hornblende biotite syenite, through leucocratic porphyritic and microsyenite to pseudo-trachyte. Within the syenites occur large xenoliths of calc-silicate rocks. The syenites are quartz-bearing linked petrologically and chemically to alkaline magmatism formed during the final development of pan-African batholiths. Geological, geochemical and geophysical investigations led to the discovery of new type of phosphate deposit occurring as apatite pegmatite ore bodies. Resources of phosphate bearing material have been estimated in the range of 0.5-1.0x10<sup>6</sup> tonnes at 5% P<sub>2</sub>O<sub>5</sub>. Trace element studies show that the syenites are high level intrusions that resulted from differentiation of parental magma and assimilation of country rocks. Tectonic setting of the syenites has been classified as within-plate granite of the attenuated continental crust. For future phosphate exploration locally and regionally, the most favourable target areas would be post-orogenic fractionated alkaline syenite bodies occurring at the margin of large granitic batholiths associated with deep seated faults.

**Key words:** Apatite pegmatite, feldspar, Syenites, quartz

### **Effect of improved cultural techniques on growth and organoleptic properties of *Corchorus olitorius* in Lusaka Province of Zambia**

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Optimum spacing and nitrogen fertiliser application rates for maximum yield and quality of edible fresh leaves of *Corchorus olitorius* were studied at the University of Zambia. Nitrogen levels were 0, 40, 80, 120, 160 kg ha<sup>-1</sup>. Intra-row spacing was 20, 30, 40 cm and broadcasting. Inter-row spacing was 40 cm in all plots. Leaf yields were higher with nitrogen fertiliser as top

dressing than the control. The highest leaf yield was 1.44 t ha<sup>-1</sup> obtained at 40 kg N ha<sup>-1</sup> with the lowest yield at 1.02 t ha<sup>-1</sup> from the control. There were little differences in crude protein and taste between the control and fertilised plots. Crude protein was highest in wide spacing (40 cm x 40 cm) and lowest in broadcasting treatments. Crude protein and taste improved where spacing was done compared to broadcasting. Positive correlation indicated that an increase in leaf yield was accompanied by crude protein increase.

**Key words:** Crude protein, nitrogen, row-spacing, taste

### **Growth and yield components of sesame in response to plant population and nitrogen in Zimbabwe**

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Seed yield of sesame (*Sesamum indicum* L.) in Zimbabwe is low compared to other countries, yet the crop is gaining economic significance. A trial was conducted at Gwebi, Zimbabwe, to evaluate the effect of plant population and fertiliser nitrogen rate on yield components of sesame landrace, Matsai. Plant populations were 100 000, 200 000, 300 000 and 400 000 plants ha<sup>-1</sup>. Nitrogen was assessed at four levels, namely, 0, 30, 60 and 90 kg N ha<sup>-1</sup>. Due to poor emergence and disease attack, the actual plant populations achieved were 78,000, 105,000, 185,000 and 224,000 plants ha<sup>-1</sup>, respectively. Neither plant population nor nitrogen levels had significant effects on leaf N concentration, plant height, seeds capsule<sup>-1</sup>, seed weight capsule<sup>-1</sup>, grain yield or oil content. Linear effects of both factors were significant (p<0.05). Seed yield was positively correlated with plant height (r=0.77) and plant population (r=0.77). Nitrogen applications above 30 kg ha<sup>-1</sup> significantly (p<0.05) increased stem N concentration. Increasing population decreased combined leaf and stem N concentration from 0.151 g N plant<sup>-1</sup> at 78 000 plants ha<sup>-1</sup> to 0.124 g N plant<sup>-1</sup> (p<0.05) at 224000 plants ha<sup>-1</sup> but the decrease was not statistically significant. Combined stem and leaf nitrogen concentration significantly increased with increase in N rate from 0.110g N/plant at 0 kg N ha<sup>-1</sup> to 0.165 g N plant<sup>-1</sup> at 60 kg N ha<sup>-1</sup>. Increasing population from 78,000 to 105,000 plants per ha had a significant interactive (p<0.05) effect at 90 kg N ha<sup>-1</sup>, whereby branches plant<sup>-1</sup> (BP<sup>-1</sup>) decreased from 16.5 at 78,000 plants ha<sup>-1</sup> to 10.2 at 105,000 plants ha<sup>-1</sup>. Nitrogen level alone had no significant effect on BP<sup>-1</sup>. Capsule number plant<sup>-1</sup> (CNP) significantly decreases (p<0.001) with increase in population from 199.6 at 78,000 plants ha<sup>-1</sup> to 103.1 at 224 000 plants ha<sup>-1</sup>. The effect of nitrogen rate on CNP was not significant. Capsule number per plant was positively correlated with BP<sup>-1</sup> (r=0.92) but negatively with population (r=-0.74).

**Key words:** Capsule, oil content, *Sesamum indicum*

### **Role of Vesicular Arbuscular Mycorrhizal fungi on the growth and nutrient uptake by Bambara groundnut**

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A study was carried out at the School of Agricultural Sciences, University of Zambia to evaluate the effect of vesicular arbuscular mycorrhizal fungi on the growth and nutrient uptake by Bambara groundnut (*Vigna subterranean*). In the first experiment, treatments were inoculated and not inoculated, and P at rates 0, 4, 8, 12, and 16 kg P ha<sup>-1</sup> as KH<sub>2</sub>PO<sub>4</sub>. The second experiment three rates of inoculums (0, 200 and 400 g inoculum per 2.8 kg in pots. Mycorrhizal inoculation resulted in 28% increase in root nodulation and increase in N uptake in the shoots (41%), root (36%) and whole plant (36%). Only K uptake in root was significantly increased (23%) in mycorrhizal plants, but there was no apparent increase in K uptake in the shoots and whole plant. Inoculation with mycorrhizae led to increase in dry matter yield of shoot (39%), root (35%) and whole plant (39%). Greater effect of inoculation with VAM was observed in the absence of added inorganic phosphorus. Addition of phosphorus up to 8 kg P ha<sup>-1</sup> increased the uptake of K in shoot and whole plants by 66 and 59%, respectively. The number of nodules per plant was also increased by 57% with the phosphorus fertilisation up to 8 kg P ha<sup>-1</sup>. Both inoculated and non-inoculated plants responded similarly to phosphorus fertilisation. Inoculation with mycorrhizal fungi alone had more effect on the N uptake in roots and root dry matter yield than fertilisation with phosphorus or interaction of mycorrhizal fungi and phosphorus fertilisation. The interaction between mycorrhizal fungi and phosphorus resulted in greater K uptake in roots of Bambara groundnut than was obtained by inoculation with mycorrhizae fungi or phosphorus fertilisation independently.

**Key words:** Inoculation, potassium, VAM, *Vigna subterranean*

### **Water use efficiency and economic effects of maize-legume intercropping system in Zambia**

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Maize-legume intercropping systems are common practice among small scale farmers in Zambia. However, the benefits of this practice are not fully understood due to inadequate information on the agronomic and economic effects of the system. Three intercropping experiments were conducted, each consisting of a legume and maize. Soyabean (*Glycine max* L) variety Kaleya, common bean (*Phaseolus vulgaris*) variety Carioca and sun-hemp (*Clofalaria juncia*) variety NIRS3 were separately intercropped with maize (*Zea mays* L) variety MM502. Each experimental unit was made up of four treatments, namely maize monocrop, legume monocrop, maize-legume intercrop and bare (unplanted plot). Intercropping improved water use efficiency, and this improvement was found to be a more economic way of growing crops than monocropping. Land Equivalent Ratio and the cropping index (CI) were 1.32 and 2.00, respectively, for the Maize-soyabean intercropping system. Similar results were observed in Maize-common bean intercropping system where the CI was 2.

**Key words:** *Glycine max*, *Phaseolus vulgaris*, *Zea mays*

### **Effect of watering interval, planting depth and soil crusting on emergence and seedling establishment of sorghum in Zambia**

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A study was conducted to investigate the effect of agronomic practices on sorghum seedling emergence and establishment in Zambia. Watering intervals had no significant effect on seedling emergence. Increasing watering interval from 2 to 8 days reduced shoot height and shoot dry weight. Shoot height and dry weight from clay loam soil was significantly ( $p < 0.01$ ) higher than from sand soil and sandy loam soil. The effect of planting depth on seedling emergence was highly significant ( $p < 0.01$ ). Seedling emergence at 15 days after planting (DAP) was significantly higher at the shallower planting depth of 3 cm (98%) than at depths of 6 cm (64%) and 9 cm (13%). Shoot height and dry mass were significantly ( $p < 0.01$ ) reduced when seeds were planted deeper than 3 cm. The effect of crusting on emergence and seedling establishment varied significantly ( $p < 0.01$ ) with soil type. Seedling emergence was 83% from sandy loam, 81% in sand and 52% from clay loam at 15 DAP. Crust strength varied with soil type, clay loam ( $3.5 \text{ kg cm}^{-2}$ ), sandy loam ( $1.54 \text{ kg cm}^{-2}$ ) and sand ( $0.9 \text{ kg cm}^{-2}$ ). Crust strength was negatively correlated with seedling emergence ( $r = -0.61$ ), shoot height ( $r = -0.72$ ), and shoot dry weight ( $r = -0.61$ ).

**Key words:** Crusting, sand loam, *Sorghum bicolor*

### **Impact of rainfall variability and agricultural factors on maize yield in Lusaka Province of Zambia**

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There are many non-climatic factors influencing the agricultural potential of an area; but of the climatic factors, the most important are the distribution in time and amount of rainfall. The purpose of this study was to probe rainfall variability based on the persistence model, which follows a theoretical distribution and the theory of runs which requires that time series of rainfall data be considered as a success or failure about a selected truncation level. We used probability sampling techniques; time series analysis, magnitude frequency analysis and the principal axis factor analysis in which 15 variable were correlated yielding six factors. The factors were then orthogonally rotated and their factor matrices interpreted in terms of content of the variable that loaded most highly. There existed high rainfall variation within Lusaka Province, while coefficients of variation showed no evident trend. Wet spells in drought years had the most severe droughts, but not the most intense droughts. The conclusion was that there was an increase in maize yield due to the strong influence of the southern oscillation index and sea surface temperatures with rainfall variability.

**Key words:** Principal factor analysis, wet spells

### **Zinc fractions and cereals response to zinc application in selected Zambian soils**

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Incidences of plant and soil Zn deficiency have been reported in many countries. The University of Zambia soil analysis laboratory has observed that a high percentage of soil samples analysed fall below the critical crop requirement limits for Zn. Field experiments were conducted at the University of Zambia, School of Agriculture Field Station to assess the response of wheat and maize to soil and foliar application of Zn. Half of each site was assigned to treatments with Zn, while the other half received foliar application. Twenty two soils were fractionated for Zn using batch extraction schemes. A pot study was also conducted in which the 22 soils were cropped in a green house to establish the pool which supplied the Zn. After six weeks of growth, the above ground parts of the plants were harvested, washed, dried and weighed for dry matter yield. The plant samples were analysed for Zn. Methods of application were significantly different for both maize and wheat, ( $p=0.0001$  and  $p=0.0043$ , respectively). Maize grain yield from the applied fields were higher ( $1.78 \text{ t ha}^{-1}$ ) than from the foliar applied fields ( $1.14 \text{ t ha}^{-1}$ ). Wheat grain yield was higher in the soil applied fields ( $3.69 \text{ t ha}^{-1}$ ) than in foliar applied fields ( $2.74 \text{ t ha}^{-1}$ ). Both crops responded to Zn application. Zinc concentrations of the crops were more in the treated fields than in the controls except for the wheat foliar applied field. Uptake of Zn by maize in the plots with soil applied Zn ranged from 31.97 to 77.23 mg, while that from foliar application ranged from 22.74 to 80.52 mg. Uptake of Zn by wheat in the plots with foliar applied Zn ranged from 5.13 to 10.11 mg, while that of the soil applied Zn ranged from 8.89 to 14.63 mg. Soil distribution of Zn was as follows; sesquioxide (45.5%) > residual (34.1%) > carbonate bound Zn (17.1%) > organic bound (9.5%) > exchangeable pool (5.5%).

**Key words:** Carbonate, foliar application, fractionation, sesquioxide

### **Response of green beans to varying rates of boron application**

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Green beans are a very important crop, feeding a large number of people in the world. However, bean yields are low, in Zambia, hence, any method resulting in enhanced green bean yield is of great importance. Boron (B) is one of the most important micronutrients necessary for bean growth and yield. A widespread deficiency of soluble boron has been reported in Zambian soils. A study was carried out to correlate two methods of boron analysis with plant B uptake, and to determine whether B application will improve crop performance. In the laboratory, 16 soils that included pairs from cropped and fallow land were extracted for B using hot-water extraction and acid extraction. A parallel study was carried out in the green house. A green bean crop was grown in each of the soils for six week period. In the field, five rates of B were applied, 0, 2, 6 and 8 kg B ha<sup>-1</sup> to two green beans crops. One foliar application at 0.45 g l<sup>-1</sup> was also used. The field experiments were conducted at Yolk Farm in Lusaka Province in Zambia, while the pot experiment was conducted at the University of Zambia green house. There was no good correlation between each of the two extraction methods and plant uptake. Foliar application at 0.45 g B l<sup>-1</sup> also did not significantly increase bean yield. Both field and green house experiments increasing rates of B did not influence ( $p<0.05$ ) plant height, pod length,

yield and quality of green beans. The early crop, which was grown purely on drip irrigation did slightly better than the second crop which received some rainfall. During the first crop, the pods were 6% longer than the control compared to only 1% in the second crop. The length of pod was found to contribute to increasing yield of green beans. The yields were 28% more than the control in the first crop and 15.6% more in the second crop. Fruit quality was not affected by increasing rates of B. However, higher packout rates were obtained in the first crop compared to the second.

**Key words:** Fallow, foliar, uptake, Zambia

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## **Residual effect of sunnhemp green manure crop on a maize**

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Maize (*Zea mays* L.) is the staple crop in Swaziland, but there have been shortfalls in production due to high cost of commercial fertilisers, among other factors. One means of addressing the problem is the use of sunnhemp (*Crotalaria juncea* L.), a green manure crop, which is cheap and easy to produce. The objective of this study was to determine whether the use of sunnhemp, as a green-manure crop can be a substitute to commercial fertilisers. A field experiment was conducted at the Crop Production Farm, Faculty of Agriculture, University of Swaziland. The design of the experiment was a split plot and the sub-plots were replicated four times. The main plots consisted of four plots where sunnhemp and commercial fertiliser treatments were the sub-plots. Treatments for the main plot consisted of: (i) control (no sunnhemp), (ii) Sunnhemp cut at full flowering and not incorporated into the soil, (iii) sunnhemp cut at full flowering and incorporated into the soil, and (iv) sunnhemp allowed to mature and its stems incorporated into the soil. Sub-plot treatments were: 0 kg fertiliser 200 kg ha<sup>-1</sup> 2:3:2 (22) + 200 kg lime ammonium nitrate (LAN, 28%), and 400 kg ha<sup>-1</sup> 2:3:2 (22) + 400 kg lime ammonium nitrate (LAN, 28%). Maize variety, SC 403, was used. Soil where no sunnhemp was applied had only 14.4% N, while 21.4% N was realised where sunnhemp was planted and not incorporated into the soil. There was 81.5% N added into the soil where the sunnhemp was cut at flowering and incorporated into the soil, while 47.7% was added where the sunnhemp was allowed to reach maturity. There was a significant ( $p < 0.01$ ) difference for maize seed yield with sunnhemp allowed to mature performing better than the other treatments. Maize seed yield where sunnhemp was allowed to reach maturity was the highest (7873 kg ha<sup>-1</sup>). It was closely followed by the treatment where sunnhemp was cut and incorporated into the soil at flowering (7728 kg ha<sup>-1</sup>). Seed yield where the sunnhemp was not incorporated into the soil was 6,546 kg ha<sup>-1</sup>, while it was 6,980 kg ha<sup>-1</sup> where there was no sunnhemp. The mean yields of commercial fertiliser levels, averaged over sunnhemp treatments, for 0, 200 and 400 kg ha<sup>-1</sup> were 6729, 7970 and 7145 kg ha<sup>-1</sup>, respectively.

**Key words:** *Clotalaria juncea*, fertiliser, Swaziland, *Zea mays*

## **Evaluation of sweet sorghum varieties and plant densities as a source of biofuel in the Lowveld of Swaziland**

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The Swaziland Water and Agricultural Development Enterprise (SWADE) is exploring water resource development in the country's river basins to appraise viable, bankable and sustainable projects. These projects are aimed at alleviating poverty of farmers in rural areas, in communities that are water stressed. Sugarcane (*Saccharum officinarum* L.), the main cash crop in Swaziland, is facing price reductions expected over the next three years. This, therefore, presented an opportunity to investigate the use of sweet sorghum (*Sorghum bicolor* L.) varieties as a source of biofuel in the Lowveld of Swaziland. The project was established on L set soils at Bhalekane Farm in the Lowveld of Swaziland. It was under sprinkler irrigation with two varieties, Urja and a landrace, each at three different plant densities, 27,778 (low), 55,556 (medium) and

111,111 (high) plants ha<sup>-1</sup>. Plant heights of the Urja and landrace after planting were 309.5 and 280.7 cm at 10 weeks, respectively. Urja had significantly longer ( $p<0.01$ ) leaves, (88.8 cm), compared to the landrace (81.0 cm), 10 weeks after planting. Leaf area index was greater for the landrace than Urja (6.4) compared to 3.9 at 10 weeks after planting. The landrace had 14.1 leaves plant<sup>-1</sup> compared to Urja, which had 11.9 at 10 weeks after planting. At harvest, plant biomass was 54.5 and 63.0 tonnes ha<sup>-1</sup> for Urja and the landrace, respectively. The biomass obtained at high, medium and low densities were 79.1, 60.2 and 36.9 tonnes ha<sup>-1</sup>, respectively. Sucrose was significantly ( $p<0.01$ ) higher for Urja (4.5%) than for the landrace (2.1%) at 13 weeks after planting. Even though sucrose was higher in Urja, it did not reach the 7.14% in the RSSC experiment. Variety Urja, at medium plant density, had the highest sucrose level (5.6%), while the landrace at low plant density had the lowest (1.5%). Urja also had significantly ( $p<0.01$ ) higher brix and purity than the landrace. Brix values were 8.4 and 7.5%, while the purity were 53.0 and 27.8%, respectively. Seed yield at harvest for Urja and the landrace were 1,383 and 2,393 kg ha<sup>-1</sup>, respectively; while for the high, medium and low plant densities the yield was 3,369, 1,699 and 597 kg ha<sup>-1</sup>, respectively. Urja had significantly more bioethanol than the landrace at harvest, but it was lower compared to others. The values for Urja and the landrace were 1,253.8 l ha<sup>-1</sup> (22.7 l tonne<sup>-1</sup> of sweet sorghum stems) and 708.8 l ha<sup>-1</sup> (10.5 l tonne of sweet sorghum stems), respectively.

**Key words:** Brix, *Saccharum officinarum*, *Sorghum bicolor*

### **Effect of intercropping sugarcane with legumes and maize on yield and quality of sugarcane**

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A sugarcane (*Saccharum officinarum* L.) intercropping study was established at Simunye Sugar Estate in the North Eastern Lowveld of Swaziland (26.20° S and 31.90° E), following a food security concern by new smallholder sugarcane farmers in the Maguga Dam Development Project. The objective of this study was to determine if intercropping sugarcane with food crops could address food insecurity for smallholder sugarcane farmers. The project was established on an R set soil under surface drip irrigation with seven replications, where each crop was grown as a sole stand and also in association with sugarcane. Sugarcane planting ridges were spaced at 1.5 m, an interrow spacing that applied to all crops. Intra-row spacing for the food crops was 10, 15 and 20 cm for cowpea, groundnut and maize, respectively. Varieties used were N23 for sugarcane, PAN 67 for maize (*Zea mays* L.), Nyanda for groundnut (*Arachis hypogea* L.) and a local variety for cowpea (*Vigna unguiculata*). Intercropping with cowpea and maize significantly ( $p<0.01$ ) reduced sugarcane yield and quality, while their (intercrops) yields were not affected. Intercropping with groundnut had no significant effect on the yield and quality, while the yield of groundnut was significantly ( $p<0.01$ ) reduced by 29%. Land equivalent ratios were 1.66, 1.39 and 1.33 for sugarcane grown in association with groundnut, cowpea and maize, respectively. Intercropping with maize was more profitable despite its detrimental effect on sugarcane yield due to selling the maize as green mealies. Yields of cowpea and groundnut were significantly ( $p<0.01$ ) reduced by 72 and 98%, respectively, as a result of intercropping in the first ratoon. The performance of maize was apparently not affected by intercropping with sugarcane in the first ratoon.

**Key words:** *Arachis hypogea*, *Saccharum officinarum*, Swaziland, *Vigna unguiculata*

## **Response of Bambara groundnut to fallowing mineral fertilisers in Swaziland**

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Bambara groundnut (*Vigna subterrenea* (L) Verdc) is an indigenous African pulse crop, with valuable nutritional values with potential for contributing to food security. In Swaziland and other countries in the Southern Africa Development Community region, farmers prefer to grow the crop on fallow land because yields are higher there than on non-fallow land. However, only about 13% of the arable land in Swaziland is fallow. Dependence on fallow land cannot sustain the production of the crop, if the claim by farmers is true. The objectives of the study were (i) to verify the claim by farmers that Bambara groundnut yields higher under fallow than on non-fallow land, and (ii) develop technology for Bambara groundnut production under non-fallow land. A pot experiment was conducted outdoors at the Crop Production Department Farm with soil from fallow and non-fallow land. Three levels each of nitrogen (0, 45 and 90 kg ha<sup>-1</sup>), three levels of phosphorus (0, 30, and 60 kg ha<sup>-1</sup>) and three levels of potassium (0, 30 and 60 kg ha<sup>-1</sup>) were applied. Each plot consisted of three plastic bags which were 30 cm high with a radius of 14 cm. Six seeds of Bambara groundnut land-race, Swazi Red were planted in each plot and later thinned to one per pot. Data showed that soil from fallow land increased seed yield significantly ( $p < 0.05$ ) by 19.8%. Neither nitrogen, phosphorus, potassium nor their interactions had significant effects on seed yield. The highest seed yield (2,823 kg ha<sup>-1</sup>) under fallow land was obtained at N-P-K fertiliser combinations of 0 N, 30 P, and 60 K kg ha<sup>-1</sup>, respectively; while in non-fallow land the highest seed yield (2,726 kg ha<sup>-1</sup>) was at an N-P-K fertiliser combinations of 45 N, 30 P, and 60 K kg ha<sup>-1</sup>, respectively.

**Key words:** Leaf area index, Swaziland, *Vigna subterranea*

## **Evaluation of maize, Bambara groundnut and groundnut mixtures**

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Intercropping or mixed cropping is an old-age cropping practice of the traditional systems of agriculture in under-developed parts of the world. It involves simultaneous growing of two or more crops on the same piece of land during a growing season. The objectives of this study were to (i) determine the effect of growing maize, Bambara groundnuts and groundnuts in monoculture or in association: and (ii) the most effective planting pattern between sowing maize and Bambara groundnuts or groundnuts on the same row or on alternate rows that has the highest yield or land equivalent ratio. A field experiment was conducted at the Crop Production Departmental Farm in Swaziland. Treatments were monoculture maize, monoculture Bambara groundnut, monoculture groundnut, maize and Bambara groundnuts or groundnut sown on the same row, and maize sown with Bambara groundnuts or groundnut between maize rows. Maize was the main crop and Bambara groundnut and groundnut were the companion crops. Maize yield was not significantly affected by growing maize in association with Bambara groundnut or groundnut. Neither planting patterns had significant effects on maize yield. However, the yield of Bambara groundnut or groundnut grown in association with maize was significantly ( $p < 0.01$ ) reduced. There were no significant differences between the planting

patterns. The intercropping advantages on yield were 4 and 6% for maize sown on the same row and maize with Bambara groundnuts sown between maize rows, respectively. On the other hand, the intercropping advantages on yield were 16 and 26% for maize and groundnut sown on the same row and groundnuts sown between maize rows, respectively.

**Key words:** *Arachis hypogea*, *Vigna subterranae*, *Zea mays*

### **Effect of witchweed control method on growth and yield of maize in Swaziland**

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*Striga hermonthica* and *S. asiatica* (L.) Kuntze is an obligate parasitic weed of maize (*Zea mays* L.), which seriously hinders the growth and reduce the yield of infected crop plants. It would be useful, therefore, to investigate the control methods on the growth and yield of maize. A field experiment was conducted at Nhlanguano Experiment Farm in Swaziland. Imidazolinone-resistant maize variety KB 04 OA10 had a more significantly ( $p < 0.05$ ) lower Striga score (1.5) than the maize variety SC 403 (2.1). The striga control method involving Bladex plus mixed with Bullet as a pre-emergence treatment, led to a significantly ( $p < 0.05$ ) lower striga score (1.4) than treating with the Bladex plus post-emergence herbicide (2.1). The interaction between four maize varieties and control methods on the striga infestation was significantly ( $p < 0.05$ ) higher for the maize varieties SC 403; selective hand-weeding treatment (Striga score 2.4) and CML-181 treated with Bladex plus as a post-emergence herbicide, (2.4) than the other treatments. The lowest striga score was observed with maize variety Ua Kayongo treated with Bladex plus only as a post-emergence herbicide which had a striga score of 1.2. The interaction between maize varieties and striga control methods on maize grain yield indicated that the maize varieties SC 403; selective hand-weeding had a grain yield of 3791 kg ha<sup>-1</sup> and SC 403 treated with Bladex plus mixed with Bullet as a pre-emergence herbicide (3591 kg ha<sup>-1</sup>), which was significantly ( $p < 0.05$ ) greater than the interactions between other maize varieties and striga control methods. The Imidazolinone-resistant maize varieties, KB 04 OA10 and Ua Kayongo had relatively lower Striga scores than maize varieties SC 403 and CML 181. The treatment involving Bladex plus in combination with Bullet as a pre-emergence herbicide, had a significant influence on reducing striga infestation and development. The pre- and post-emergence herbicides mixture of Bladex plus and Bullet was successful in effecting striga control and sustainable weed control over the selective hand-weeding method throughout the experimental period. The Imidazolinone-resistant maize varieties have a potential for reducing striga growth and development, and combined with the use of pre- and post-emergence herbicides, the yield of the farmers in witchweed infested fields in Swaziland.

**Key words:** Herbicide, imidazolinone, resistance, Striga

**Sokoine University of  
Agriculture, Tanzania**

### **Effect of growth media and nutrients on growth of rose flower plants**

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A study was undertaken using soil, gravel and coconut coir dust (CD) and decreasing concentrations of the essential nutrients in complete plant nutrient culture solution currently used at Kiliflora in Arusha, Tanzania. The objective was to identify the best growth media for raising rose flower plants and the optimal levels of nutrient concentrations for optimal rose plant growth, yield and quality of the rose flowers. Five rates used by Kiliflora farm (coded as 1x), that is 1x, 0.5x, 0.25x, 0.125x and 0.0625x were applied to each growth media, and replicated three times. Rose plant cuttings raised in a propagation unit, were transplanted to the growth media in plastic pots. Half a litre of each of the five concentrations of the complete plant nutrient culture solution was added once to each pot per day and the same amounts were added nine times to each of the pots for the CD and gravel medium, respectively everyday. At the end of the 3-month growth period the rose plants were harvested by cutting the whole plant just above the first internode from the surface of the growth media in the pots. The growth media at various concentrations had no significant ( $p>0.05$ ) effect on the stem length, stem thickness, bud width and heights. However, the nutrient concentration in the culture solution had significant effects on the above plant parameters. The effect of nutrient concentrations in the rose plants did not follow well defined trends. However, based on the quality of the rose flowers, and the mean nutrient contents in the rose plants, the CD was the best growth medium, followed by gravel and soil. The optimal level of nutrient concentrations was the 0.25x (25%).

**Key words:** Coconut coir, gravel, soil, Tanzania

### **Mineral nutrient status of soils of ARI-KATRIN for paddy rice production in Tanzania**

Mghase, J.J.

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A study was undertaken to assess the mineral nutrient status of the soils of ARI-KATRIN, in Tanzania for rice production. With the exception of iron and manganese, soils of the upland ecology had low levels of the nutrients compared to the established critical levels. Nitrogen content of the soils of the lowland non-flooded ecology was found to be low and the soils of the lowland flooded ecology had low N and P contents. With respect to nutrient contents in the rice plants, N, Ca and Mg in the three ecologies were low. In addition, the contents of Cu, Zn and Fe from the upland ecology were low. Manganese contents were also low in rice plants from the lowland flooded ecology. Low levels of nutrients, especially in soils of the upland ecology could be due to the sandy texture of the soils, which enhances nutrient leaching, hence, poor nutrient and moisture retention capacities.

**Key words:** Flooded, nitrogen, phosphorus, upland ecology, zinc

## **Effect of residual tied ridges on soil physical factors and sorghum yield in semi-arid central Tanzania**

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With the increasing use of conservation tillage, many questions have been raised on the viability of using residual tied-ridging system. This study was conducted in semi-arid central Tanzania on a continuing three year old tillage trial comprising No-till (T1), Shallow tied ridges (T2) and deep tied ridges (T3) to evaluate the effect of residual tied-ridges on soil physical and hydrological properties, as well as sorghum grain yield. Land preparation involved the removal of crop residues from the previous season and a minimum maintenance of residual ridges. Bulk densities were significantly ( $p < 0.05$ ) different between T1 and other treatments only at mid-season within 0-10 cm soil layer. Weekly gravimetric soil profile moisture content in 0-50 cm soil layer was significantly ( $p < 0.05$ ) different treatments on the 4<sup>th</sup>, 8<sup>th</sup> and 17<sup>th</sup> week after planting. Profile moisture content variations of between 40.4 to 59.4 mm, 48.4 to 77.7 mm and 57.5 to 85.5 mm for T1, T2 and T3, respectively, were observed. However, T1 had significantly ( $p < 0.05$ ) higher cumulative infiltration than T2 and T3. Tillage significantly ( $p < 0.05$ ) affected the soil surface roughness indices (SSRI) in the order of 68.7 to 106.3 for T1, 152.8 to 169.2 for T2 and 173.2 to 180.0 for T3. Generally, the SSRI decreased during the season. Seedling emergence was significantly ( $p < 0.05$ ) higher in T1 by 5.7 and 14.2%, than in T2 and 4.1%, and T2 and T3, respectively. T2 and T3 had significantly ( $p < 0.05$ ) higher grain yield by about 0.85 and 1.06 t ha<sup>-1</sup>, respectively. Grain yield was more than doubled by residual tied-ridges compared to the control. Residual tied ridges are thus a viable tillage system which can reduce tillage and ridging cost as well as increase sorghum grain yield in semi-arid areas.

**Key words:** Conservation tillage, no-till, shallow, tie ridges

## **Response of Chinese cabbage to farmyard manure slurry on an acid soil in Tanzania**

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A glasshouse pot experiment was conducted at the Sokoine University of Agriculture in Tanzania, to evaluate the response of Chinese cabbage (*Brassica campestris* L) to farmyard manure slurry (FYM-slurry) applied to an acid soil. The soil was categorised as of low fertility status and the nutrient contents in the FYM-slurry (solid and liquid portions) was medium. FYM-slurry at equivalent rates of 0, 166.6, 208.33, 250, 291.67, 333.33, 375, 416.67 and 500 m<sup>3</sup> ha<sup>-1</sup> were applied to the buckets 7 days from the transplanting (Chinese cabbage seedlings) date in six equal splits at intervals of ten days. Application of FYM-slurry significantly increased fresh and dry matter yields, and macronutrient contents of the plants. The increases were attributed to rises in the fertility status consequent to plant nutrient release by FYM-slurry. The micronutrient contents of the Chinese cabbage decreased with FYM-slurry application and this was probably due to the increase in soil pH.

**Key words:** *Brassica campestris*, macronutrients, pH

## **Soil and water conservation in young tea fields in Usambara Mountains of Tanzania**

Sanga, B.N.K.

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A survey was conducted in the Usambara Mountains in Tanzania to identify factors responsible for the failure of smallholder tea growers to adopt recommended soil and water conservation practices, particularly in young tea. The survey revealed that most smallholder tea growers were not aware of splash and sheet erosion; hence, needed education on the subject. Mulching in young tea fields was also not widely done in the steep slopes (15 – 50%) of Usambara Mountains. Lack of enough mulching materials was a reason for the poor adoption of the practice. Recommended mulching materials (Guatemala grass) were found to have another important function of feeding stall-fed livestock. A field experiment to study the effectiveness of high density tea rows as live barrier in young tea fields was also conducted at Marikitanda Tea Research Station in Tanga. Initial results indicated a significant difference in canopy cover development and yield across the treatments ( $p < 0.01$ ). Canopy cover was highest in high density tea rows (52%) and lowest in Guatemala mulch (31%). The control (no soil and water conservation practice) and vetiver grass had 32.2 and 31.7% canopy cover, respectively. Yield recorded was 44.9, 20.1, 17.7 and 14.0 kg made tea  $\text{ha}^{-1}$ , for Guatemala mulch, high density tea rows, control and vetiver grass, respectively. Soil erosion was highest in vetiver grass (28.6  $\text{t ha}^{-1}$ ) followed by the control, high density tea rows and Guatemala mulch (26.0, 23.4 and 7.8  $\text{t ha}^{-1}$ , respectively). However, vetiver grass trapped 52.0  $\text{t ha}^{-1}$  of soil, which was significantly higher ( $p < 0.01$ ) than in any other practice. The control and the high density tea live barrier practices lost 20.8 and 15.6  $\text{t ha}^{-1}$  of soil. No deposition was observed on Guatemala mulch plots. Generally, initial results showed that high density tea rows when used as live barrier showed low positive effects; however, there was an indication of fast development of its canopy cover.

**Key words:** Canopy, Guatemala grass, mulching, soil erosion

## **Response of maize to nutrients and filtermud applied to a Dystric nitosols**

Luambano, N.

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A pot experiment to study the response of maize (*Zea mays* L) to nitrogen, phosphorus and filtermud applied to a Dystric nitosols was carried out at the Sokoine University of Agriculture in Tanzania. The Dystric nitosols was characterised by low total organic carbon, N exchangeable  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ , CEC, plant available P and a very strongly acid reaction. The filtermud contained low amounts of nutrients and had a very mild alkaline reaction. Fifty four, 12 kg soil samples of the soil were taken into 10 litre capacity plastic buckets and thoroughly mixed with nitrogen as  $(\text{NH}_4)_2\text{SO}_4$  at the rates of 0, 50 and 100  $\text{kg N ha}^{-1}$ , P at 0, 75 and 150  $\text{kg ha}^{-1}$  and filtermud at the rates of 0, 15 and 30  $\text{t ha}^{-1}$ . The soil-N-P-filtermud treatments were incubated at field capacity for 3 weeks. Then, five maize seeds were planted in each pot and allowed to grow for 6 weeks. Application of N and P alone and in combinations, and N-P-filtermud combinations significantly increased dry matter yields and total N, P and K in the maize plants. The increase in the N and P contents in the plants were attributed to increased availability of N and P added to the soil as

N and P fertilisers, as releases from the filtermud through decomposition and mineralisation. Further, improvement of the physical, chemical and biological properties of the soil by the filtermud could have contributed to increase the N and P. However, application of filtermud alone decreased the N and P contents of maize plants and this was attributed to the immobilisation of these nutrients in the soil.

**Key words:** Nitrogen, phosphorus, potassium, *Zea mays*

### **Rainwater harvesting techniques for improving smallholder maize production in semi-arid areas of Morogoro in Tanzania**

Bwana, T. N.

Sokoine University of Agriculture, Tanzania

A study was conducted at Morogoro in Tanzania during long rains ('Masika') to evaluate the effect of *in-situ* rainwater harvesting techniques in improving maize yield. Three commonly used techniques, ridging after planting (RA), ridging before planting (RB), and tied ridging (TR) were tested against a no tillage practice locally known as "kuberega" (K) on an Oxic Paleustalf soil. Maize (*Zea mays* L.) variety TMV1 was the test crop. The total rainfall received during the 2001/02 growing season was 562 mm with a series of dry spells. Moisture content at 0-15 and 15-30 cm depth, was measured twice weekly. Significantly ( $p < 0.05$ ) higher soil moisture variation and lower moisture content were noted in treatment K than in the other treatments. Treatments RB and TR had lower moisture variations and higher moisture content throughout the season. Significant differences ( $p < 0.05$ ) were observed among the treatments in runoff loss, infiltration, grain yield and biomass. Maize yield ranged between 2.97 and 3.89 t ha<sup>-1</sup> for treatments K and RB, respectively. Runoff loss was highest for K and least for TR. Treatments K and RA did not differ significantly but differed from RB and TR ( $p < 0.05$ ). Soil loss had a similar trend as runoff. More runoff loss was recorded early than late in the season. On-ridge infiltration was not significantly different for treatments TR, RA and RB, but was higher than the control (K) ( $p < 0.05$ ). On-furrow infiltration, however, had a reverse order with K having higher rates. Bulk density in both depths (0-15 and 15-30 cm) was not different ( $p > 0.05$ ), however, treatment K had slightly higher bulk density.

**Key words:** Infiltration, ridging, runoff, *Zea mays*

### **Management of micronutrients in volcanic soil for maize production in Tanzania**

Lisuma, J.B.

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A study was conducted in field and glasshouse conditions to identify and correct some micronutrient constraints in Mpangala volcanic soil for optimisation of maize yields. Soil analysis revealed the level of Cu to be 0.14 mg kg<sup>-1</sup>, which was ranked as deficient; Zn 0.86 mg kg<sup>-1</sup> (marginal) and boron was 0.52 mg kg<sup>-1</sup> (medium). In the first pot experiment, P and N were applied at rates of 160 and 240 mg kg<sup>-1</sup>, respectively. However, in one treatment a higher rate of 320 mg P kg<sup>-1</sup> was applied in order to test whether a higher rate of P was required in

Mpangala soil. Boron was applied at 0 and 2 mg kg<sup>-1</sup>, Cu at 0 and 5 mg kg<sup>-1</sup>, and Zn at rates of 0 and 10 mg kg<sup>-1</sup>. A combination of Cu, N and P increased yields dramatically. The treatment that received the high P rate of 320 mg kg<sup>-1</sup> together with N, B, Cu and Zn had significantly ( $p < 0.05$ ) higher dry matter (DM) yield than the Cu treatment. Plant leaves had very low concentrations of Cu, followed by Zn. Copper at a rate of 20 mg Cu kg<sup>-1</sup> was the best in Mpangala soil. In the field experiment, a significantly ( $p < 0.05$ ) higher grain yield of 5.84 t ha<sup>-1</sup> was obtained when 2.5 kg Cu ha<sup>-1</sup> was applied.

**Key words:** Boron, copper, nitrogen, Zinc

### **Banding methods and organic matter addition for improving dissolution and availability of phosphorus from Minjingu phosphate rock in Tanzania**

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A study was conducted at Sokoine in Tanzania to evaluate the effect of Minjingu Phosphate Rock (MPR) banding and some manipulations within the band, on maize yield. Treatments were: varying depth of incorporating MPR, and organic materials (plant residues). Specifically, treatments tested were 20-cm MPR + O.M. band, incorporated down to the 10 or 20 cm depth, 20-cm MPR alone band, incorporated to the 10 or 20 cm depth, 2-5 cm width strip banded MPR, broadcasting MPR (only for field) and control. Some banding treatments significantly ( $p < 0.05$ ) increased dissolution and availability of P from MPR. For example, the Minjingu PR plus organic matter increased DM yields from 3.17 to 56.32 g pot<sup>-1</sup> and 7.13 to 76.24 g pot<sup>-1</sup>, and P uptake from 2.75 to 83.24 mg pot<sup>-1</sup> and 4.72 to 118.40 mg pot<sup>-1</sup> for Sasanda and Magadu soil, respectively. Banding of MPR can be a good method of MPR application in acid and high P fixing soils, especially when MPR is incorporated together with organic residues.

**Key words:** Maize, P fixing soil, plant residues

### **Residual tied ridges and farm yard manure application on sorghum yield in semi-arid areas of Tanzania**

Kabanza, A.K.

Sokoine University of Agriculture, Tanzania

Soil physical management involves better understanding of the dynamics of soil physical properties. This study was conducted in semi-arid central Tanzania on a continuing five years old tillage trial comprising No-till (NT), shallow tied ridges (STR), deep tied ridges (DTR) and annually made tied ridges (ADTR). The objective was to evaluate the effect of residual manured tied ridges on soil physical and hydrological properties as well as sorghum grain yield. Land preparation involved removal of crop residues from the previous season and a minimum maintenance of the residual tied ridges. The test crop was sorghum, variety *Tegemeo*. There was no significant ( $p < 0.05$ ) difference in residual OM content among tillage treatments. Tillage significantly ( $p < 0.05$ ) affected soil surface roughness indices among tillage treatments (NT, STR and DTR). It was 185% high in the residual tied ridges compared to the control. Cumulative infiltration was 285.66 mm hr<sup>-1</sup> before planting and 412.83 mm hr<sup>-1</sup> at harvest.

Weekly gravimetric soil profile moisture content in 0.-50 cm soil layer significantly ( $p < 0.05$ ) influenced by treatments throughout the season, and was higher in the residual tied ridges compared to the control. A significant difference in bulk density was observed between treatments only at harvest and within 30-50 cm soil layer. Total porosity values were not significantly different among tillage treatments. Seedlings emergence and number of plants at harvest were significantly ( $p < 0.05$ ) higher in DTR than in other treatments. The annually made tied ridges led to higher sorghum grain yield ( $2.17 \text{ t ha}^{-1}$ ) than in the control. Grain yield under residual tied ridges after five seasons was comparable to the yield from annually made tied ridges. Residual tied ridges can thus be utilised for up to five seasons. The reduced tillage and ridging cost as well as the increased sorghum grain yield under the residual tied ridges are likely to make the system attractive to farmers in semi-arid areas.

**Key words:** Moisture, no till, organic matter

### **Heavy metal uptake by vegetables grown on sewage sludge-treated soils in Tanzania**

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A pot experiment was conducted to determine the uptake of heavy metals by Chinese cabbage (*Brassica chinensis*), lettuce (*Lactuca sativa* L.) and cowpea (*Vigna unguiculata*) from sewage sludge-treated soils. A sandy loam (pH 6.9) and a loamy sand (pH 7.1) were amended with sewage sludge at rates of 0, 10, 20 and  $30 \text{ t ha}^{-1}$  (oven-dry weight basis). Characterisation of the soils and the sludge indicated that the soils contained small amounts of heavy metals, thus having a low potential for causing pollution; while the sludge had elevated levels of heavy metals. Amendment with sewage sludge significantly ( $p < 0.05$ ) increased the yields of all vegetables. Chinese cabbage dry matter yields ranged from 3.34 to 15.89, and 9.83 to  $17.09 \text{ g plant}^{-1}$  for Msimbazi and Mjimpya soils, respectively. For lettuce, they ranged from 3.43 to 14.29, and 6.69 to  $13.63 \text{ g plant}^{-1}$ , for Msimbazi and Mjimpya soils, respectively; while for cowpea they ranged from 5.89 to 15.74 and 13.77 to  $19.94 \text{ g plant}^{-1}$  for Msimbazi and Mjimpya soils, respectively. The highest yields were with applications of sewage sludge at  $30 \text{ t ha}^{-1}$ . Vegetable uptake of heavy metals revealed higher uptake of Cd, Cu and Zn by all vegetable species with sewage sludge application. The uptake of Pb and Cr was low and not consistent with the rates of sewage sludge application. There were significant differences among the uptakes of heavy metals by the different vegetable species. DTPA-extractable Cu and Zn concentrations in post-harvest soil increased significantly with sewage sludge application. However, the increase of DTPA-extractable Pb and Cd was not consistent with the rates of application. Chromium was not detected in the post-harvest soil. Vegetables grown in amended soils showed higher N and P concentrations than control plants. There should be close monitoring over the use of the sludge for edible crop production.

**Key words:** *Brassica chinensis*, cadmium, chromium, copper

### **Effect of some industrial organic wastes on maize grain yield and soil properties**

Timbula, K.M.

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A study was conducted at Magadu in Morogoro, Tanzania to evaluate paper sludge and pyrethrum marc as alternative sources of plant nutrients. Maize was the test crop and four rates of paper sludge and pyrethrum marc (0, 10, 20, and 30 t ha<sup>-1</sup>) on air-dry basis were applied to soil. Paper sludge and pyrethrum marc were alkaline and acidic in reaction, respectively. Paper sludge had high C/N (37.7), C/P (245) and Ca/Mg (105.22) ratios. The high C/N and C/P ratios meant that biological immobilisation of nitrogen and phosphorus would be the major limiting factors for this waste to be used as a source of plant nutrients. High Ca/Mg ratio indicates that paper sludge can be used as a liming material. Maize grain yield in plots amended with pyrethrum marc increased from 0.64 to 3.33 t ha<sup>-1</sup> with increasing rates of the material; while in plots treated with paper sludge, grain yield decreased from 1.43 to 0.52 t ha<sup>-1</sup> as the rate of paper evaluated. Increasing rates of the wastes changed the bulk density from 1.50 to 1.38 mg cm<sup>-3</sup>. For pyrethrum marc treated plots, soil pH, OC, total N, extractable P and exchangeable Ca<sup>2+</sup>, Mg<sup>2+</sup>, and Na<sup>+</sup> and CEC increased with increasing rates of the waste. Copper and Fe were significantly low relative to the control, while Zn was higher than the control. Soil pH, exchangeable Ca and CEC of the plots amended with paper sludge increased with rates of the material, from 5.28; 2.61; 0.57 to 7.79; 14.20, respectively. Increasing the rates of paper sludge had a negative effect on exchangeable Mg<sup>2+</sup>, K<sup>+</sup>, Na<sup>+</sup> and extractable P. Total nitrogen and organic carbon were not statistically different from the control. Copper content increased with increasing rate of paper sludge (0.71 mg kg<sup>-1</sup> for the lowest rate and 0.81 mg kg<sup>-1</sup> for the highest rate of paper sludge). Zinc was not statistically different from the control.

**Key words:** Copper, iron, paper sludge, pyrethrum, Tanzania

### **Effect of gypsum and lime on subsurface acidity and phosphorus utilisation by plants in Morogoro, Tanzania**

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A study was conducted to assess the effect of gypsum and lime on subsoil acidity and phosphorus utilisation by plants grown on an acid soil. The Minjingu Phosphate Rock (MPR) and Triplesuperphosphate (TSP) were used as sources of P. Makanya Gypsum Rock (MGR) and commercial lime from ABCON Ltd, Dar es Salaam, were used as gypsum source and liming material, respectively. Treatments included single and combined effects of lime or gypsum alone, lime or gypsum + TSP, and lime or gypsum + MPR in both pot and field experiments. In the pot experiment, the arbitrary lime or gypsum rate of 0.8 t Ca ha<sup>-1</sup> and the lime requirement for topsoil (0.5 t Ca ha<sup>-1</sup>) or subsoil (2.5 t Ca ha<sup>-1</sup>) were used. In the field experiment, the lime or gypsum rate of 0.8 t Ca ha<sup>-1</sup> was used. Lime was more effective than gypsum in ameliorating acidity and aluminum toxicity. Gypsum was more effective than lime in amelioration of total acidity and exchangeable aluminum in middle and subsoil. Yields from lime/gypsum + TSP treatments were higher than lime/gypsum + MPR. Extractable P was higher in gypsum treatments than in lime in the field experiment. There were no significant differences in extractable P

between lime and gypsum treatments. Gypsum was more effective in releasing Ca than was lime.

**Key words:** Aluminium, calcium, Minjingu phosphate rock

### **Evaluation of the soil fertility status of smallholder tea farms of Rungwe District in Tanzania**

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A study was carried out in Rungwe district, Mbeya region in Tanzania to evaluate the soil fertility status of small holder tea farms for production potential. Composite soil and tea leaf samples were taken from thirty tea smallholder farmers. Soils were of mixed textural classes including sand, clay, sand loam, sand clay loam, silt clay and clay loam. All the soils had good textural composition for tea production. Soil pH in all the samples was slightly acidic, which is conducive to tea production. Total soil N and S, exchangeable  $\text{Ca}^{2+}$ ,  $\text{K}^+$  and  $\text{Na}^+$  ranged from low to medium; while Bray1 extractable P and exchangeable  $\text{Mg}^{2+}$  were markedly deficient in the soils. DTPA extractable Cu was deficient in most soils, while Zn was largely sufficient. DTPA extractable Fe and Mn were high in all the soils. Analysis for nutrient concentration in the third leaves of tea plants showed large deficiency of total N and P in the leaves. Most of the leaf samples showed sufficient concentration of K, Ca Mg and S. The third leaf concentration of Cu and Zn ranged from deficient to sufficient, while wide spread deficiencies of Fe in the leaves were observed in most of the leaf samples.

**Key words:** DTPA, manganese, nitrogen, phosphorus, potassium

### **Changes in soil phosphorus fractions in relation to phosphorus sources and residual phosphorus availability**

Kosia, E.N.M.

Sokoine University of Agriculture, Tanzania

A study was conducted in the laboratory to assess changes in soil phosphorus fractions in relation to phosphorus sources and residual availability and uptake. Residual P was compared with fresh P application at rates of 60 and 180 mg P kg<sup>-1</sup>. Three soils with high P fixing capacity, Sasanda (umbric Andosol), moderate fixing capacity, Suluti (Rhombic Acrisol) and low fixing capacity, Nkundi (chromic Acrisol) from the Southern Highlands of Tanzania were used. A portion of soil (1.0 g) was sequentially extracted with deionised water, 0.5 M sodium bicarbonate ( $\text{NaHCO}_3$ ), 0.1 M sodium hydroxide (NaOH), 1.0 M hydrochloric acid and a combination of concentrated sulphuric acid and hydrogen peroxide ( $\text{H}_2\text{SO}_4 + \text{H}_2\text{O}_2$ ). The release and distribution of various P fractions were dependent on the P source and soil characteristics. In Sasanda and Suluti soils, TSP gave significantly higher effects than MPR. The trends of most P fractions in Nkundi soil were opposite of those in Sasanda and Suluti soils, except for NaOH-P<sub>o</sub> and  $\text{H}_2\text{SO}_4 + \text{H}_2\text{O}_2$ -P which were similar. The FeO-P<sub>i</sub> was highest in Nkundi and lowest in Sasanda. High rates of fresh applications of TSP significantly increased DMY. Dry matter yield increased significantly ( $p < 0.05$ ) at high application rates in Sasanda. There was only slight increase over

low residual application rates of MPR, MPR caused slight increases in DMY and Ca uptake over TSP, and Ca uptake increased with P application rates. Potassium concentration in plants was deficient in all soils, and its uptake decreased with increase in Ca concentration in plants. Phosphorus caused a slight increase in Mg concentration in plants.

**Key words:** Calcium, Minjingu, TSP, Tanzania

### **Land suitability evaluation based on land mapping units and agroecological zones in Morogoro Rural District in Tanzania**

Mathew, L.

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A study was conducted in Morogoro Rural District in Tanzania to assess land evaluation based on land mapping units (LMUs) and Agro ecological zones (AEZs) as a land unit criterion for land suitability classification at district level in Tanzania. The study comprised of agro-economic survey using semi-structured questionnaires, compilation of land resource and Agro-economic databases, and physical and Agro-economic land suitability evaluation of LMUs and AEZs. This was done for maize, paddy and sesame as the main land utilisation types (LUTs). The Automated Land Evaluation System (ALES) was used. It was observed that parts of land units, Val (50%), Va2 (AEZ IX (50%), MO21 (35%), AEZ V (35%), AEZ VI (35%), Pe3 (30%), AEZ III (20%) and AEZ VII (5%), were moderately suitable for maize production. The rest were either marginally or not suitable for maize production. Parts of land units, Val (50%) and AEZ VII (45%), were highly suitable for paddy production, while land units Pel (55%) and AEZ IV (75%) were moderately suitable for paddy production. The rest were either marginally or currently not suitable for paddy production. Also parts of land units, AEZ IX (50%), AEZ V (35%), Pe3 (30%), AEZ VI (5%) and AEZ VII (5%), were moderately suitable for sesame production. The rest were either marginally or currently not suitable for sesame cultivation. The major limiting factors for the productivity of these LUTs were erosion hazards, oxygen unavailability to root zones, rooting condition, moisture availability, nutrient availability and nutrient retention. There was positive correlation between ALES predictions and farmers' reported yields and gross margins with correlation ranging from 0.3 to 0.7 and 0.2 to 0.8 for yields and gross margins, respectively. Predictions of yield and gross margins by ALES were better ( $p < 0.05$ ) when AEZs were used as a land unit criterion for land suitability evaluations.

**Key words:** ALES, land mapping units, paddy production

### **Effect of amendments on soil properties and maize yield grown on sodic soil in Arusha, Tanzania**

Gwasso, N.C.W.

Sokoine University of Agriculture, Tanzania

A study was conducted at Mto wa Mbu in Arusha, Tanzania to evaluate the effect of some amendments on soil properties and yield of maize grown in sodic soils. The soil was alkaline, clay loam textured and compact (bulk density ranging from 1.39 to 1.45 g cm<sup>-3</sup>). Gypsum was applied at 0, 7, 15, 22.5 and 30 t ha<sup>-1</sup> and sulphur at 0, 1.4, 2.9, 4.3 and 5.7 t ha<sup>-1</sup>, corresponding

to 0, 25, 50, 75, and 100% of laboratory gypsum requirement. Farmyard manure was applied at 0 and 20 t ha<sup>-1</sup>. In gypsum-treated plots, maize grain yield ranged from 0 (control) to 1.32 t ha<sup>-1</sup>. Maize grain yields in sulphur amended plots ranged from 0 to 0.32 t ha<sup>-1</sup> and that of FYM treated plots ranged from 0 to 0.35 t ha<sup>-1</sup>. When gypsum and sulphur were combined with FYM, maize grain yields ranged from 0 to 1.42 and 0 to 0.53 t ha<sup>-1</sup>, respectively. Therefore, maize grain yield was significantly higher in gypsum and FYM when applied alone than in sulphur amended plots. But it was much higher when gypsum and sulphur were mixed with FYM. Application of amendments was uneconomical due to low maize grain yield. Residual available P, CEC, %OC, total N, exchangeable bases, CEC in the plots amended with gypsum, sulphur and FYM increased in the top 15 cm of soil relative to the control. Soil pH and ESP in all treated plots was significantly reduced except in S<sub>25</sub> and S<sub>50</sub> treatments. DTPA extractable Zn, Fe, Cu and Mn increased slightly following the application of amendments. Soil pH and Ca were significantly affected (p<0.05). ECe was slightly correlated with the yield. The rest of the variables (P, %OC, total N, exchangeable bases and DTPA extractable Zn, Fe, Cu, Mn) were not linearly correlated with the yield.

**Key words:** CEC, farm yard manure, gypsum, iron, zinc

### **Response of maize to tithonia diversifolia applied to a Kanhaplic haplustults in Tanzania**

Baltazary, U.M.

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A glasshouse pot in experiment was conducted at Sokoine University of agriculture, Morogoro, Tanzania to evaluate the response of maize (*Zea mays*) to *Tithonia diversifolia* green manure applied to a Kanhaplic haplustults. The *T. diversifolia* green manure contained high levels of most of the plant nutrients and 78% moisture content. Eighteen 20 kg, 6 mm sieved composite soil sample portions of the Kanhaplic haplustults were weighed into 20 litres capacity plastic buckets. The weighed soil were thoroughly mixed with fresh finely chopped *Tithonia* leaves at the rates of 0, 2, 5, 7, 5, 10, 12, 5, 15, 17.5 and 20 t ha<sup>-1</sup> on dry weight basis. The soil-green manure mixtures were incubated at field capacity moisture content for two weeks. Maize seeds were planted in each bucket and the maize plants were allowed to grow for six weeks. The whole maize plants above the soil levels were then harvested and dried at 70 °C to constant weights. Maize plant dry matter yields significantly increased with levels of green manure. Both macro- and micro-nutrients followed suite in the maize plants. Improvement in the other attributes of soil fertility and productivity contributed to the observed increase in dry matter yields and nutrient content of maize plant.

**Key words:** Green manure, Kanhaplic haplustults, *Zea mays*

### **Soil fertility status of rice growing areas of Kilimanjaro region in Tanzania**

Amur, N.

Sokoine University of Agriculture, Tanzania

This study was conducted to assess the fertility status of the soils of rice growing areas of Same District in Tanzania. Thirty soil samples were collected from ten different sites where rice was grown. Three bulk soil samples were currently collected from Kisiwani, Ndungu and Kihurio for pot experiments. The response of rice (*Oryza sativa* L.) variety super SSD5 to N, P and K, as well as to different levels of Zn were assessed in a glasshouse experiment where plants were grown for 56 days. All the soils were deficient in N. About 53% of the soils had low available P. All the soils had adequate levels of K, Ca, Mg and Na, with the exception of soils from Ndungu, which had low K. Also, all of the soils had low Zn levels, except two sites which had adequate Zn. Soils from Mbugani had low Fe, while the rest had adequate Fe and Cu. Application of N, P and K increased rice dry matter yield in all the soils used. Zinc supplementation in addition to NPK increased rice dry matter yield. The uptake of each nutrient applied was consistent with the dry matter yields increases. Most of the soils under rice cropping in the district were deficient in N, P and Zn.

**Key words:** Magnesium, nitrogen, *Oryza sativa*, phosphorus

### **Effect of organic residues in sulphur induced acidity amelioration for maize growth in cashewnut growing soils of Tanzania**

Omolo, J.O.

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A study was conducted in a glasshouse to examine the effect of organic residues, namely, cowpea (*Vigna unguiculata*), pigeonpea (*Cajanus cajan*), cordia (*Cordia* sp.) and wild spikenard (*Hyptis suaveolens*), in ameliorating the soil acidity induced by H<sup>+</sup> oxidation of sulphur in cashewnut growing soils of Mtwara in Tanzania. The organic residues were characterised for their chemical composition and, thereafter, incorporated into soil containing different amounts of S calculated based on the application rates. They were incubated for 60 days, with weekly sampling for laboratory analysis. A similar set of experiment was done, with maize planted in pots, for a period of 30 days after which dry matter yields were determined. There was a significant ( $p < 0.05$ ) reduction in soil pH with increased levels of sulphur, as a result of sulphur oxidation in the soil with consequent production of sulphuric acid. This was further proved by proton budget analysis, which showed increased proton generation with increased levels of S. Maize dry matter yields decreased ( $p < 0.05$ ) with increased S level (which depressed soil pH). Addition of the organic residues led to amelioration of the soil acidity. There were variations between residues attributed to the differences in alkalinity among the organic residues. The order of soil pH increase by the organic residues was pigeonpea > cordial > wild spikenard > cowpea. Among the residues, legume species had higher alkalinity than non-legumes. There seemed to be a variation within plant species (in the case of cowpea) due to age of the plant, with lower alkalinity upon aging of the plant.

**Key words:** Cordia, cowpea, pigeonpea, wild spikenard

## **Effect of limestone, Minjingu phosphate rock and green manure on acid soil in Tonga, Rwanda**

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A study was conducted to assess the effect of limestone, Minjingu Phosphate Rock (MPR) and green manures (GMs) on maize yield, soil properties and nutrient uptake at Butare in Rwanda. Treatments tested in the greenhouse were four rates of limestone applied either alone or in combination with MPR and/or green manures. In the field experiment, treatments were an absolute control, recommended rate of NPK and burnt lime, NP and limestone, combinations of any two of the following materials: limestone, MPR, Tithonia GM, Tephrosia GM, and combinations of three of these amendments. Application of GMs improved the supply of N and K, while limestone played a great role in reducing exchangeable Al. A significant ( $p < 0.05$ ) contribution of P was from MPR. A combination of MPR, GMs and limestone supplied ample amounts of N, P, K, Ca and Mg, and reduced exchangeable Al. However, high rates of limestone decreased DM yield and nutrient uptake in the treatment with the three amendments. A significant increase in DM yield was obtained in pots, which received a combination of low rate of limestone (25% of the lime requirement), MPR and GMs. In general, Tithonia gave higher yields than Tephrosia. These results were consistent with the higher quality of Tithonia biomass relative to Tephrosia biomass. Green manures in combination with MPR increased P uptake significantly. Nutrient concentrations from both field and pot experiments indicated serious deficiencies of P, K and N consistent with soil analysis data, but Ca, Mg, Zn and Cu were in the sufficiency range. Using a combination of moderate rates of limestone, MPR and GMs is the best strategy in improving acid soils in Tonga, Rwanda.

**Key words:** Exchangeable aluminium, NPK, Tephrosia, Tithonia

## **Soil fertility status of after four years of continuous application of different nutrients in Tanzania**

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A study was undertaken to assess the fertility status of soils following four years of continual application of different nutrients. The soils were from Mlingano, Nkundi and Sasanda, which are classified as Rhodic Kandistox, Acruoxic Kandistult and Dystric Haplustand, respectively. Application of different nutrients, except nitrogen, led to build up in levels of applied nutrients. Application of Minjingu Phosphate Rock (MPR) or TSP increased levels of Bray 1-P from low to medium and high levels, respectively, in Nkundi and Mlingano soils. In Sasanda soil, Bray 1-P remained below 5 mg P kg<sup>-1</sup> despite application of TSP and MPR. In Nkundi soil, MPR application raised Bray 1-P from 5.0 to 41.7 mg P kg<sup>-1</sup>, whereas in Mlingano soil Bray 1-P was raised from 2.6 to 39.4 mg P kg<sup>-1</sup>. Application of TSP raised Bray 1-P to above 105 mg P kg<sup>-1</sup> in Mlingano and Nkundi soils, but only to 4.7 mg P kg<sup>-1</sup> in Sasanda soil. Zinc and copper increased to sufficient levels in all soils due to application of zinc sulphur and copper. Use of TSP or MPR decreased soil pH in Mlingano and Nkundi soils, but the decrease was less in soil treated with MPR. However, in Sasanda soil MPR increased soil pH from 5.0 to 5.3 and there occurred no shift in pH in plots treated with TSP. Residual P increased significantly ( $p < 0.05$ )

maize dry matter and grain yields in plots treated with TSP and MPR. The increase in dry matter and grain yields due to residual P from MPR and TSP were comparable. In Mlingano and Nkundi soils, dry matter yields ranged between 7.29 and 64.77 g pot<sup>-1</sup>, whereas in Sasanda soil it ranged between 2.12 and 22.10 g pot<sup>-1</sup>. At Nkundi site, residual P from MPR and TSP gave yields for 4.23 and 4.73 t ha<sup>-1</sup>, respectively. Yield in absolute control and control for P treatments were 1.03 and 1.83 t ha<sup>-1</sup>, respectively.

**Key words:** Minjingu, phosphate rock, TSP, Tanzania

### **Effect of phosphate rock placement methods in-crop rotation of organic residues on phosphorus availability and maize yields in phosphorus fixing soils of Tanzania**

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A study was conducted to evaluate the effect of Minjingu phosphate rock (MPR) placement methods and organic residues on P availability and maize yields in two soils with P fixing capacities. Observations from two field experiments, one at Sasanda, Mbeya and another at Magadu, Morogoro were continued to evaluate the effect of progressive addition of organic materials (OM). One field experiment was carried out at Sasanda to evaluate the effects of different rates of OM applied together with MPR. For the continued experiment, treatments were control, broadcasted MPR, 2 - 5 cm width strip banded MPR, 20-cm wide MPR band incorporated to 10 or 20 cm depth, and 20-cm MPR band + OM incorporated down to 10 or 20 cm depth. For the new experiment, treatments tested included control, broadcasted MPR, 2 to 5 cm width strip banded MPR, 20-cm wide MPR band incorporated to 20 cm, and 20-cm band MPR + OM applied together at 2, 4, 6 and 8 t ha<sup>-1</sup> and incorporated down to 20 cm depth. Continued incorporation of OM banded together with MPR significantly ( $p < 0.05$ ) improved MPR dissolution, P availability, and increased grain yield. This was supported by highest maize grain yield (3.01 t ha<sup>-1</sup>) obtained from these continued observations, which was higher than the maximum (2.27 t ha<sup>-1</sup>) obtained in the previous study from the MPR + OM incorporated down to 20 cm depth. The results of the new experiment showed that banding of MPR together with OM at the rates of 2, 4, 6 and 8 t ha<sup>-1</sup> significantly ( $p < 0.05$ ) increased MPR dissolution, P availability, and maize grain dry matter yields. The increase was in proportion with the increased rates of OM. For example, in the pot experiment, MPR + OM increased DM yields from 14.14 to 76.17 g pot<sup>-1</sup> and 4.10 to 70.87 g pot<sup>-1</sup> in Magadu and Sasanda soils, respectively. In the field experiment, MPR + OM at 2, 4 and 6 t ha<sup>-1</sup> increased extractable P in the soil from 0.18 to 0.474 mg kg<sup>-1</sup> and maize grain yields from 0.36 to 3.38 t ha<sup>-1</sup>. The increase was also proportional to the increased rates of OM. The highest extractable P (0.47 mg kg<sup>-1</sup>) and grain yields (3.38 t ha<sup>-1</sup>) were observed from MPR + 6 t OM ha<sup>-1</sup>.

**Key words:** Minjingu, P dissolution, strip banded

## **Strategies for establishing adequate phosphorus levels in phosphorus fixing soils in Tanzania**

Eliuth, S.N.

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A study was conducted to establish adequate levels of phosphorus in three soils with different P fixing capacities. The objective of the study was to identify rates of P required for optimising maize dry matter grain yields, and associated available P levels in the soils. These soils were from Magadu, Mrogoro District, classified as *Oxic Haplustult*, Sasanda, in Mbozi District, classified as *Drystropept* and Nkundi in Nkasi District, classified as *Acruoxic Kandiusult*. A pot experiment was conducted at the Sokoine University of Agriculture (SUA), while the field experiment was carried out at Sasanda in Mbozi District in Mbeya region. Treatments were 0, 40, 80 and 160 mg P kg<sup>-1</sup> of soil for Nkundi; 0, 100, 200 and 400 mg P kg<sup>-1</sup> of soil for Magadu; and 0, 800, 1600 and 3200 mg P kg<sup>-1</sup> of soil for Sasanda soil. For field experiment the treatments were 0, 800, 1600 and 3200 kg P ha<sup>-1</sup>. The sources of P were TSP and MPR. The tested crop was maize (*Zea mays* var UH 615). Both TSP and MPR were effective sources of P in the soils studied. Both significantly ( $p < 0.05$ ) increased dry matter (DM) and grain yield, P uptake and available P over the control by 97.7, 95.8 and 95.3%, respectively in Sasanda soil. This was supported by the highest grain yield, DM yield, and P uptake of 2.97 t ha<sup>-1</sup>, 64.18 g and 124.8 mg kg<sup>-1</sup> at the rates of 3200 kg P ha<sup>-1</sup> and 3200 mg kg<sup>-1</sup>, respectively in Sasanda soil. However, MPR was slightly less effective than TSP for most of the aspects studied. The optimum rates were 160, 200 and 3200 mg P kg<sup>-1</sup> for Nkundi, Magadu and Sasanda soils, respectively under pots. In Sasanda field experiment, P application did not significantly ( $p > 0.05$ ) increase available P and the available P was below the critical level. The rates of 1600 kg P ha<sup>-1</sup> gave the highest grain yield of 2.97 t ha<sup>-1</sup>. Results indicated that MPR has the potential of supplying P for maize production, therefore, it could be used as an alternative source of P to TSP.

**Key words:** Maize, Minjingu, Tanzania, *Zea mays*

## **Spatial and temporal variability of soil fertility under rainwater harvesting systems in the Makanya River catchment in Tanzania**

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A study was conducted to assess the spatial and temporal variability of soil fertility under rainwater harvesting systems in three villages along the toposequence on the Makanya river catchment, in Tanzania. Random soil samples were collected from Makanya, Mwembe and Tae villages, for characterisation of physical and chemical soil properties on the catchment. Runoff water samples were collected and analysed for plant nutrients. GPS and GIS were used for positioning both soil and water sampling points and to establish geospatial information database and generate maps of the study area. Geostatistical analysis was done for soil fertility surface interpolation. From the study, more than 92% of the interviewees practiced RWH systems. Soil fertility attributes showed that total nitrogen was very low to medium level (0 - 0.5%), soil pH ranged from strongly acid to moderately alkaline, while exchangeable K<sup>+</sup> on the upper zone was very low (0 - 0.13 cmol kg<sup>-1</sup>) for the majority of samples (62%). Available P was adequate (39.49 - 81.16 mg P kg<sup>-1</sup> soil) only on the lower zone. Fertility attribute maps on the mid and

upper zone tended to be systematically distributed following the slope facet, while on the lower zone; maps showed the patterns distribution to follow availability of harvested rainwater. Generally, most of the soils under rainwater harvesting in the area had low fertility.

**Key words:** Nitrogen, pH, potassium, run off, toposequence

### **Soil moisture balance prediction under tillage methods in semi-arid areas in Tanzania**

Chikondi, P.

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Soil moisture balance computer simulation models play a very important role in providing scientists with a tool able to rapidly calculate the magnitude of various processes affecting the field water balance under different climatic and vegetation conditions. This study evaluated the performance of three soil water balance computer simulation models for different soil water conservation tillage plots. The three models were SWAM (Soil Water Availability Model), a sub-model of PARCH; PATHSMM (PARCHED-THIRST soil moisture model), a sub-model of PARCHED-THIRST and BUDGET, and a sub-model of IRSIS (irrigation Scheduling Information System). The study was conducted at Sokoine University of Agriculture (SUA) farm in Morogoro, Tanzania, on a sand clay soil. Maize (*Zea mays* L) was planted for two consecutive rainy seasons. The tillage treatments were: flat cultivation (FC), zero tillage (ZT), staggered ridges (SR), contour ridges (CR) and tied-ridges (TR). All the models used had better soil moisture balance simulations on the flat cultivation (FC) treatment than other treatments. However, the models tended to overpredict soil moisture content. The performance of the PATHSMM model was remarkable on all tillage treatments. There was good correlation between simulated and actual soil moisture content. Correlation coefficients ranged between 0.64-0.95 for PATHSMM simulations. The BUDGET model needs to be improved by incorporating tillage, macropore flow and crusting factors in it. The PATHSMM model needs to be tested on other soil types and treatments.

**Key words:** Budget, parch, swam, Zero-tillage, Tanzania

### **Effect of tillage induced soil physical and hydrological properties on soil water balance and growth of sorghum in arid areas of Tanzania**

Guzha, A.C.

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Conservation of soil water is an important management objective for crop production in the Semi-arid topics. Identification of the best tillage methods to achieve this objective is, thus imperative. The integrated effects of tillage-induced soil physical and hydrologic properties on soil water balance on a sandy loam soil were evaluated. The experiment consisted of tillage treatments, namely tied ridging (TR), no till (NT), disc plough (DP), strip catchment tillage (SCT), and hand-hoe (HH). Field measurements included soil moisture content, bulk density, surface roughness, infiltration, surface runoff and evaporation. Infiltration rates and depths were higher for the tilled soils than the untilled soils. The DP treatment had the highest cumulative infiltration. TR had low cumulative infiltration not significantly different from the

NT treatment. SCT and HH had almost similar values, but less than DP. The Kostiakov (1932) and Philip (1957) infiltration models were fitted to the infiltration data and gave good fit. Depression storage determined using Mitchell and Jones (1976) depth-storage model was highest in the TR treatment. The higher the surface roughness the greater the depression of storage volume. Random roughness decreased exponentially with increase in rainfall. Tillage increased total porosity and DP plots had the highest values. However, total porosity decreased with cumulative rainfall. A more open tillage-induced surface structure increased evaporation losses, particularly during the first stages of evaporation. This resulted in higher cumulative losses for the DP and HH tilled soils than the other treatments. It appeared that the acclaimed beneficial “soil mulch” effect was masked by the initial higher evaporation losses from the tilled soils under the atmospheric evaporative demands of the study area. There were significantly higher levels of soil moisture in the TR plots than the other treatments. Higher soil moisture contents were associated with treatments having higher depression storage. The tied ridged plots had the least runoff, while the NT plots recorded very high runoff losses. Saturated conductivities estimated using van Genuchten model were highest in the DP soils and lowest in the NT soils.

**Key words:** Bulk density, Kostiakov, no-till, tied ridges

### **Effect of tillage, soil surface management and oxygen supply on soil properties and performance of tropical grain crops**

Cosmas, M.M.

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Two field experiments were conducted at two localities on the IITA farm to investigate the effect of tillage, residue management and soil surface manipulations; and oxygen supply on soil properties and the performance of some tropical grain crops. The localities were lowland planted with rice and upland planted with maize, soybean and cowpea. Treatments for the lowland rice experiment were tillage operations (puddling and zero-tillage), residue management (with and without burning) and oxygen supply (with and without oxygen) using calcium peroxide. Puddling resulted in higher grain yield than zero-tillage. However, all the other crop growth parameters were not influenced by the tillage operations. Burning the residues significantly ( $p < 0.05$ ) improved the rate of seedling emergence, period to ultimate emergence and number of seedlings that attained ultimate establishment. However, it reduced plant height and the number of tillers per plant. Under both tillage systems, oxygen supply did not affect the performance and yield of rice regardless of whether the residues were left on the soil surface unburnt or burnt. Treatments for the upland crops experiment were oxygen supply and soil surface manipulations. The latter included bare surface, mulch cover alone, or in combination with either chiseling or compaction. Mulching in combination with compaction increased soil bulk density and reduced total porosity at seedling emergence. It also reduced water infiltration before sowing and at harvest compared to the other soil surface manipulations. Oxygen supply alone generally had no significant ( $p > 0.05$ ) effect on plant height and leaf production of maize, soybean and cowpea. However, it enhanced seedling establishment and root growth of cowpeas, but suppressed root weight of maize. Reduction in growth of maize, soybean and cowpea was generally more marked when the soil was mulched and compacted. Mulching in combination with chiselling, on the other hand, improved the growth of the crops. Superimposing oxygen supply on soil surface manipulation significantly influenced seedling

emergence and establishment, and root growth of soybean and cowpea. However, oxygen supply delayed the mean period to ultimate seedling emergence in soybeans on the bare or compacted and mulched soil. Cowpea tap root length was markedly enhanced by oxygen supply under mulch alone and mulch in combination with chiselling.

**Key words:** Burning, calcium, mulch, peroxidase, zero tillage

### **Procedure for determination of sub-models for crop and land management under Morogoro conditions in Tanzania**

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One of the most useful means of ameliorating land degradation through sediment losses is application of soil prediction models. These associate all sources of information including soil physical characteristic data, long term weather data as well as crop management data into a prescribed categorisation, effective in conservation. The purpose of this study was to develop a procedure for determining crop and land management factor(s) sub-models for soil loss prediction under Morogoro, Tanzania condition. The Pascal Programme was employed for the procedure. The procedure involved calculation of the C (Cover and Management factor) and P (Support practice factor) and then compared the outputs with desired management factors set for the specified location. Weather and soil data, and crop canopy were considered in the determination of effective parameters for soil loss prediction. There was a good correlation between soil loss and rainfall intensity, rainfall amount, canopy cover, organic carbon content as well as runoff for all rainfall events and treatments. The correlation coefficient ranged from 0.50 to 0.99. For the correlation coefficient for average runoff and sediment loss was 0.86, 0.95 and 0.99 for cropped, natural vegetated and bare plots respectively. The overall correlation coefficients of for runoff and sediment losses at different storms ranged from 0.83 to 0.98. The correlation coefficient for soil loss and rainfall intensity was 0.64, 0.50 and 0.60 for cropped, natural vegetated and bare plots, respectively. Rainfall intensity and amount, canopy cover, soil organic carbon as well as runoff variables correlated better with soil losses.

**Key words:** Crop canopy, rainfall intensity, sediment loss

### **Erosion prediction models for western Uluguru Mountains in Tanzania**

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Physically based erosion prediction models developed in the past to assess soil erosion, have been found to be difficult to apply by soil conservationist. Moreover, they are best applicable to areas where they were developed. Development of site specific erosion prediction models could ease the assessment of erosion effects for various areas of equal agro-ecological zones. A study was conducted to develop and validate a site specific erosion prediction model in the western part of the Uluguru Mountains in Tanzania. Topographic survey was done to assess the terrain elevations of the catchment. Long-term rainfall data from 11 stations in the Uluguru Mountains were analysed for seasonal rainfall, length of growing season and start and end

dates of dry and rainy seasons. Since the catchment terrain was highly steep; rainfall in the Uluguru Mountains was highly variable and unpredictable. Soil loss for 10 and 20 m slope lengths showed no significant difference ( $p < 0.05$ ), but there was a significant difference between 20 and 30 m slope length. Soil loss increased while runoff decreased with slope length. There was a reduction in runoff rate and soil loss in terraces compared to non-terraced fields. Soil depth ranged from 0-00 cm, with the convex slope having shallow soil depth and concave slopes having moderately deep soil. Soil had low penetrometer resistance ranging from 0.37 to 1.028 MPa. The textural class of the soil was clay with a bulk density of  $1.1 \text{ g cm}^{-3}$  at a depth of 0-25 cm,  $1.2 \text{ g cm}^{-3}$  at a depth of 25-65 cm and  $1.3 \text{ g cm}^{-3}$  at a depth of 65-100 cm. The effect of slope on organic matter was observed to increase from 8.9% at the top slope to 9.5% at the bottom slope. Soil pH changed from acidic at the top to neutral at the bottom slope. The soil had very rapid hydraulic properties, slope length (L), slope steepness (S), runoff (RO). Soil loss relationships fitted a linear regression model of the form  $SL = C(S + L + RO) - K$ , where SL stands for soil loss, C is a constant, S is slope steepness, L is slope length, RO is runoff and K is an intercept. The developed erosion prediction model was found to be valid and useful in estimating the respective parameter in the study area.

**Key words:** Rainfall, run off, slope, soil loss, terrace

### **Effect of rainfall and catchment characteristics on runoff yield in semi-arid areas of Tanzania**

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A study was conducted in Kisangara, Tanzania to investigate effect of rainfall and catchment characteristics on runoff yield and to develop and test an empirical model for semi-arid conditions. The experiment consisted of catchment length (viz: natural vegetation and bare and compacted). The study period covered two rainy seasons, the short and long rainy seasons. Runoff yield from 60 and 120 m<sup>2</sup> catchments was measured using a runoff collecting system. Rainfall, soil particle size distribution, soil moisture, infiltration rate and soil bulk density were also monitored throughout the rainy seasons. Catchments at 18 percent slope generated a significantly ( $p < 0.05$ ) higher mean runoff yield than those the catchments at 6 percent slope at rainfall "e" 6 mm. Similarly, catchments at 15 percent slope generated a significantly ( $p < 0.05$ ) higher mean runoff yield than catchments of 6 percent slope at a rainfall amount "e" 6 mm. The runoff yield generated from catchments at both 15 and 18 percent was not significantly different from the 6 m and 12 m length catchments. Total runoff yield generated from the 6 m length catchments was 9 percent more than the total runoff yield generated from the 12 m length catchments for the two rainy seasons. Mean runoff yield from bare and compacted catchments was significantly different from the runoff yield generated from natural vegetated catchments. The runoff yield from bare and compacted catchments at 18 percent slope was highly correlated with the rainfall characteristics ( $r = 0.95$ ). Overall, correlation coefficient between observed and predicted runoff of the empirical model developed was high (0.84) indicating that the model is suitable for semi-arid conditions of Tanzania.

**Key words:** Bulk density, infiltration, slope, soil moisture

### **Relating erosivity factors to soil loss in Hombolo and Morogoro sites in Tanzania**

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This study was conducted at Morogoro and Hombolo in Tanzania. Ten runoff plots were established, four at Hombolo and the rest at Morogoro. Five erosivity factors were regressed to ascertain the best fit on the soil loss. The plots had different treatments of canopy cover for each of the seven rainstorms recorded during the cropping season.  $EI_{30}$  compound erosivity factor and runoff had high coefficients of determination of 0.92 and 0.69, respectively. There was a significant difference in soil loss between bare plots and other plots with crop cover. However, the difference in runoff amounts was insignificant.

**Key words:** Canopy cover, erosivity, rainstorm, runoff,

### **Rainfall erosivity in Tanzania**

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A study was conducted aimed at making an iso-erodent map of Tanzania. The steps were to collect rainfall data from selected meteorological stations; select erosivity index for calculating the erosivity of storms; model the erosivity using easily available rainfall parameters; extrapolate the model to a large number of rainfall recording stations; and map the erosivities. Eleven meteorological stations were selected for modelling erosivity. Using  $EI_{30}$  index, daily erosivities of 10 217 storms from the stations were calculated using information obtained from the charts of daily rain gauge recording. Ten-year averages were used in order to portray long term trends. A highly significant correlation between daily amount of rainfall and erosivity was observed. A multivariate linear prediction model was obtained for predicting monthly erosivity. The model was based on more easily available rainfall parameters of average monthly total rainfall, average number of days per month receiving rainfall of at least one millimetre, and the average maximum daily rainfall of the month. The prediction model was used to calculate the mean monthly erosivities of 347 stations from all over the country. The mean annual erosivities of the stations were obtained by summation of the mean monthly erosivities. The mean annual erosivities of the stations were entered in the map of Tanzania at a scale of 1:7,000,000, and an iso-erodent map was obtained. Areas of high erosivity were associated with areas of high rainfall. Highest risk areas were found in Rungwe/Ileje districts in the Southern Highlands of Mbeya region, where erosivity values of up to 2,105 joules per hectare observed. Other potential risk areas included around Mt. Kilimanjaro in northern Tanzania, western parts of Lake Victoria, and eastern parts of Lake Tanganyika. Other areas included some parts of Ruvuma region, especially the eastern parts of Lake Nyasa; the Zanzibar Island, and the coastal areas. Low risk areas were found in central regions of Dodoma and Singida, and some areas bordering these regions. Others included some parts of Kilimanjaro region particularly in same district where erosivity values as low as 176 joules per hectare were observed. An erosivity map shows in general, the areas where concerted efforts needed to conserve natural resources may be required (high risk areas).

**Key words:** Erosivity map, index, prediction model

## **Comparative evaluation of rainfall erosivity indices and erosion risk in Morogoro and Kilosa Districts in Tanzania**

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Soil loss and runoff data from two field experiments at two sites in the Sokoine University of Agriculture farm, were used to evaluate the commonly used rainfall erosivity indices under different soil cover management practices. The management practices were Bare fallow (BF), Permanent grass (PG), Flat cropping (CP), Ridge cropping (CR), Coarse mesh (CM), Medium mesh (MM), and Fine mesh (FM). Four erosivity indices were tested; rainfall amount,  $R$  (mm) and rainfall energy,  $E$  ( $J m^{-2}$ ). The other two were compound indices. The  $EI_{30}$  index ( $MJ mm ha^{-1}$ ) combining the Total rainfall energy ( $E$ ) and maximum 30-minute rainfall intensity ( $I_{30}$ ), and the  $AI_m$  index ( $cm^2 h^{-1}$ ) combining rainfall amount ( $A$ ) and maximum rainfall intensity ( $I_m$ ). The erosivity indices tested namely, the  $EI_{30}$ ,  $AI_m$ , Total rainfall energy and Rainfall amount were equally and highly correlated to soil loss ( $p < 0.05$ ). Runoff was also tested and gave inconsistent results. Correlation coefficients between runoff and soil loss were low and insignificant ( $p > 0.05$ ) ( $r = 0.001$  to  $0.37$ ); correlation coefficients were high and significant ( $p < 0.05$ ) ( $r = 0.75$  to  $0.88$ ). A regression model for Tanzania developed by Nyenza (1996) to estimate long term monthly  $EI_{30}$  erosivity was validated using rainfall data collected during the two experiments. A paired t-test showed no significant difference ( $p < 0.05$ ) between observed and estimated erosivity, with a high pearson correlation coefficient ( $r = 0.76$ ). The model was used to calculate long term  $EI_{30}$  erosivity for 22 rainfall recording stations in Kilosa and Morogoro districts. Erosivity values were plotted on a map of both districts at a scale of 1:500,000. Based on this, an iso-erodent map was developed. Areas of high erosivity (up to  $1,134 J ha^{-1}$ ) were associated with high rainfall areas on the windward slopes of the Uluguru, Nguru and Udzungwa mountains. The area east of Kilosa, bordering Dodoma region experienced lowest erosivity ( $400 J ha^{-1}$ ).

**Key words:** Iso-erodent map, mesh, rainfall energy, ridge cropping

## **Validation of soil water balance models for crop assessment and yield prediction under Tanzanian conditions**

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Information gathering for early warning and crop assessment in Tanzania is still based on physical inspection of standing crops in fields. Physical inspection is based on sown area, the state of crop development towards maturity, and the prevailing and anticipated weather conditions (during and after) at the time of inspection, and the extent of crop attack by pests and diseases. The process is subject to human error and it is also time consuming. Developments in computer simulation models may provide an efficient method for analysis of data for early warning and crop assessment. This study aimed at validating Irrigation Scheduling Information System (IRSIS) and Crop Growth and Irrigation Scheduling Model (CRPSMW), which are soil water balance simulation models for crop assessment and prediction of grain yields. Five stations *viz.* Ilonga Agricultural Research and Training Centre, Msimba Foundation Seed Farm, Selian Agricultural Research Institute, Arusha Foundation Seed Farm, and Tanzania Pesticides Research Institute were selected for this study. Input data for the models comprised

of weather, crop and soil data. Weather data were of a 10 year period whereas for the crop data were for 3 to 10 years. The IRSIS model appeared to overpredict grain yield of maize, sorghum and wheat with a fair level of precision. On the other hand, the CRPSMW model results were not significantly different ( $p < 0.05$ ) from the actual grain yields of maize, sorghum, wheat and beans. The simulated grain yields for the different planting dates falling on or after the probable date for start of the growing season during the long rains for both Morogoro and Arusha, were not significantly different ( $p < 0.05$ ) from the actual grain yield. Although there was good agreement between the actual and the CRPSMW model simulated grain yields, mean values for predicted grain yields were consistently smaller than for actual grain yields. These results indicate that the subroutine in the IRSIS model that considers runoff is inadequate and needs to be reformulated and/or allowance should be given for calibration of the model with respect to the runoff component.

**Key words:** CRPSMW, IRSIS, maize, sorghum, wheat

### **Estimating crop and soil management factors of the universal soil loss equation for erosion prediction in Tanzania**

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One of the appropriate tools for predicting soil erosion in planning for soil conservation measures is the application of soil erosion predictive equations or models. Although many equations exist for this purpose, they cannot be directly applied to Tanzanian conditions since their developments were done in different conditions. This study was conducted at the Sokoine University of Agriculture in Tanzania, runoff plots with the aim of developing crop functions, as useful data in estimating the crop and soil management factor, C, of the USLE or its revised version (The RUSLE) for adaptation for use under Tanzanian conditions. Crop height and canopy curves for maize and sorghum were developed using the data collected during the 1998 season and functions relating crop height and crop canopy cover with yield for a three year period (1994, 1995 and 1998). All equations developed gave relatively high coefficients of determination ( $R^2 = 0.72 - 0.99$ ), which were significant ( $p < 0.05$ ). The equations show existence of a relationship between crop canopy cover and crop height, with yield for both maize and sorghum crops. The predicted and measured C factor values for maize crop for the 1998 season were 0.147 and 0.086, respectively. For the sorghum crop, the values obtained were 0.158 and 0.100, respectively. Also, a crop development curve was estimated from the development functions relating yield and crop growth parameters (canopy cover and crop height) and the average curve, which related the crop development ratios to crop growth period ratios. This curve was used to estimate the long term C factor value. From the growth curve, the value of 0.136 was estimated. This was reasonable when compared to the estimated C factor values for individual years.

**Key words:** Crop cover, maize, RUSLE, sorghum, USLE

## **Land use/cover changes and their influence on landslides in northern slopes of the Uluguru Mountains, in Tanzania**

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This study was conducted to assess land use/cover changes and their influence on the occurrence of landslides in the northern slopes of Uluguru Mountains, Tanzania. The study focused on the determination of the historical land use/cover changes between 1964 and 2004; evaluation of the biophysical and socio-economic factors influencing land use/cover changes; and examination of the influence of land use/cover changes on the occurrence of landslides. Field survey, remote sensing and GIS techniques were employed to assess land use/cover dynamics. Landslides were mapped through field surveys using GPS and imported GIS environment. A survey was conducted to collect information on socio-economic activities responsible for land use/cover changes and on landslides. The study demonstrated that land use/cover was dynamic and varied spatially both in terms of coverage and change. Natural vegetation was increasingly replaced by cultivation and urbanisation. Change to rainfed agriculture was more intensive on the mountain ridges by two-fold that of mountain foothills. Urban expansion was very rapid on undulating plains at a mean rate of 15 ha per year compared to 2 ha per year on the mountain foothills, and <1 ha per year in the mountain ridges. Geomorphic characteristics, soils, rainfall distribution and demographic changes were key factors influencing land use/cover dynamics. Land use/cover dynamics (increase in rainfed and irrigated agriculture) greatly influenced the occurrence of landslides ( $R^2=0.89$ ). The observed land use/cover dynamics and their relationship with the occurrence and frequency of landslides call for further research on the effectiveness of different land use options on landslide rehabilitation.

**Key words:** Cover dynamics, geomorphic, GIS, urbanisation

## **Spatial and temporal assessment of soil erosion hazard in Mbinga District in Tanzania**

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Many watershed management decisions would be aided by an understanding of soil loss, erosion characteristics and mapping of erosion hazards areas. A study was carried out to prepare thematic maps using the RUSLE model, Remote Sensing and GIS technology to produce spatial and temporal erosion hazard map for Mahenge village in Mbinga district in Tanzania for the years 1991 to 2000. In the RUSLE model, different procedures were used to obtain its factors. The LS factor was obtained using the DEM, and ARC-VIEW software; K-factor was obtained from the soil map; and Cover and Practice factors were adopted from literature after extraction of land cover/land use from satellites images. Rainfall data were obtained from observation done at Litembo Mission meteorological station for 25 years. RUSLE factors with associated attribute data were digitally encoded in a GIS database to eventually create five thematic layers. Simultaneous overlay operation of these five layers produces polygonal layer, each polygon of which is a homogeneous area with respect to each of the five factors. The model calculation applied to the resultant polygonal gave values of soil loss. In the year

1991, the results were, areas with soil loss of 0-5 t ha<sup>-1</sup> yr<sup>-1</sup> total 1021.26 ha<sup>-1</sup> (64.74%); 5-12 t ha<sup>-1</sup> yr<sup>-1</sup>, total 388.100 ha (24.93%); and areas with soil loss 12-25 t ha<sup>-1</sup> yr<sup>-1</sup> total 96.16 ha (6.18%); 25-60 t ha<sup>-1</sup> yr<sup>-1</sup> was 28.4 ha (2%); while area with soil loss of 60-24 t ha<sup>-1</sup> yr<sup>-1</sup> was total 33.9 ha (2.18%). In the year 2000, the results were, areas with soil loss of 0-5 t ha<sup>-1</sup> yr<sup>-1</sup> total 961.12 ha (61.74%); 5-12 t ha year<sup>-1</sup>, total 423.59 ha (27.21%); and areas with soil loss of 12-25 t ha<sup>-1</sup> yr<sup>-1</sup> total 114.20 ha (7.34%); 25-60 t ha<sup>-1</sup> yr<sup>-1</sup> was 31.28 ha (2%); and areas with soil loss of 60-245 t ha<sup>-1</sup> yr<sup>-1</sup> was total 26.62 ha (1.71%). The spatial and temporal hazard map shows that the areas in which soil erosion was reduced is 218.44 ha (14.27%) and the ones in which soil erosion had been increased from 1991 to 2000 were 281.20 ha (18.11%). Areas that soil erosion values had not been increased or decreased in the village are 1053.27 ha (67.83%). Soil erosion estimated values showed similar behaviour between the GIS, RUSLE and Remote Sensing technique, with those obtained from seasonal estimates done at same site using runoff plots. Using runoff plots for determination of soil erosion in the 1995/96. The results were Ngolo cultivation 4.52 t ha<sup>-1</sup> yr<sup>-1</sup>, bench terraces 4.76 t ha<sup>-1</sup> yr<sup>-1</sup> and flat cultivation is 83.22 t ha<sup>-1</sup> yr<sup>-1</sup>. These results shows that GIS Remote Sensing techniques can be used as a tool for determining RUSLE factors such as LS factors, land use/cover factors and support practice factors.

**Key words:** ARC-VIEW, DEM, K-factor, remote sensing, RUSLE

### **Soil erosion effects on crop yield trends under long-term rainfed agriculture in Tanzania**

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A study was conducted at the Sokoine University of Agriculture in Tanzania on the impact of soil erosion on crop yield under rainfed agriculture over four consecutive growing seasons. Runoff and soil loss generated during every rainstorm was collected for the determination of runoff and soil loss. Soil physical-chemical properties were analysed. Crop water requirements and moisture balance indicated a fluctuation in moisture levels as explained by levels of the ratio of the actual crop evapotranspiration ( $ET_a$ ) to the maximum crop evapotranspiration ( $ET_m$ ),  $ET_a/ET_m$  values ranged from 0.61 in 1994 season to 0.92 in the 1997 season. The study revealed that the effect of erosion on productivity is difficult to evaluate, since erosional factors do not work in isolation. Although erosion changed soil properties and removed nutrients, a measure of the amount of erosion was not found to be a sufficient indicator of decline in productivity. Moisture availability and levels of management on the farm were central in influencing crop yields.

**Key words:** Evapotranspiration, moisture balance, run-off

## **Evaluation of proportioning water-division structures on irrigation water delivery under a traditional farmer-managed system in the Usangu Plains of Tanzania**

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This study was conducted to evaluate the performance of proportioning weirs for equitable distribution of irrigation water supply with a view to improving performance in a traditional farmer-managed irrigation system in the Usangu Plains in Tanzania. Five proportioning weirs were designed and installed along the Herman canal, to deliver water to seven branch canals. Flows to each branch canal were measured. The discharge data along with climatic data were used in computing and assessing adequacy and equity of irrigation water supply, hydraulic sensitivity of canals and productivity of land and water. Comparative performance indicators developed by the International Water Management Institute (IWMI) were applied in order to compare performance of Herman canal irrigation with others and the seven cultivated areas served by the branch canals of Herman canal. A structured questionnaire was administered in order to obtain information on irrigation and land use practised by farmers. The Herman canal supplied enough water for irrigation during the season. However, farmers at the head and middle reaches abstracted more water than they required and caused a supply shortage to farmers at the tail-end reach. Nevertheless, equity of water supply during the same season was fair. This was an improvement over the past experiences before installation of the proportioning weirs. Generally, the productivity of land and water in the scheme were low. The relatively low values of output per irrigation supply, suggested that the efficiency with which water was being used in the scheme was rather low as reflected by the wasteful use of water, especially in the upper reaches. The survey demonstrated that farmers still lacked basic understanding of irrigation scheduling and irrigation water management as a whole, which led to some areas being over-irrigated, while others faced water shortage.

**Key words:** Herman canal, hydraulic sensitivity, IWMI, Weirs

## **Interventions and their effects on farmer managed irrigation schemes in Tanzania**

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This study aimed at evaluating the effects emanating from intervention on farmer-managed irrigation schemes was carried out at Musa Mwinjanga Irrigation scheme in Tanzania. Results showed that the scheme was operated at low efficiency. The conveyance, distribution, application and project efficiencies were 53.6, 53, 59.8 and 31.7 respectively. Low irrigation efficiencies were attributed to high conveyance losses due to the pervious nature of volcanic soils and poor command of the canals. Most of the canals ran below field levels. Other reasons included high operation losses due to poor water management practices, lack of water control facilities and application losses arising from poor land levelling. Seasonal mean relative water supply (RWS) for plots varied between 0.96 and 2.92 due to inadequate irrigation scheduling and lack of flow measuring facilities. The overall seasonal mean RWS for the plots was 1.83, indicating inequity of water distribution among the plots. There was no significant

difference ( $p>0.05$ ) in adequacy of supply. This implies that farmers in sampled blocks were adequately irrigating at more or less equal proportion as per crops water requirements. Organisation of the scheme was found to be fairly appropriate. However, operation and maintenance activities were not timely, effectively and efficiently carried out. Natural drainage and slopes within the scheme were not efficiently used and managed; hence, the waterlogging problems in lowland areas of the central part of the scheme.

**Key words:** Conveyance losses, irrigation scheme, volcanic soil

### **Irrigation scheduling based on penetrometer depth technique**

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Efficient and profitable irrigation scheduling strategies are needed, particularly in the arid and semi-arid region of Tanzania where available water resources are becoming more limited due to population growth and climate change. Salinisation of ground water resources due to inappropriate water use is equally threatening large areas of productive irrigated land. To help sharpen the predictive capability of farmers with regard to soil water status, a study to model a simplified approach to irrigation scheduling, based on soil resistance to penetration, was undertaken at Sokoine University of Agriculture in Tanzania. Two locations representing two different soil types, namely, clay soil (S1) and sand clay loam soil (S2) were used. Each location comprised of three blocks, which were further subdivided into three plots. Three irrigation timing schedules were allocated to the plots. Penetration depth at randomly selected spots was measured before and after irrigation of all the plots. Penetration depth was linearly related ( $r = 0.91$  for S1 and  $r = 0.82$  for S2) with soil moisture content within the zone of penetration. Beyond average penetration depth, soil moisture content for S1 correlated poorly ( $r = 0.32$ ) with average penetration depth, while S2 correlated relatively highly ( $r = 0.78$ ). However, the multi-variable model (root length and average penetration depth as variables) showed improved and highly positive correlation ( $r = 0.94$  for S1 and  $r = 0.96$  for S2) with root zone moisture content beyond the penetration depth. Calibration of an individual soil type would make it possible for the relationship to be developed between penetration depth and depth of irrigation application; otherwise the models would simulate soil moisture content. Model validation using the t-test showed no significant difference ( $p>0.05$ ) between observed and simulated values for all the three models developed. The observed and simulated moisture contents of both models 2 and 3 in each of S1 and S2 were compared using the t-test. The results showed no significant difference ( $p>0.05$ ) although the mean simulated root zone moisture content of model 2 was closer to the mean observed root zone moisture content than the mean simulated value of model 3 for both locations. It is clear that the penetrometer depth approach can be used to indicate soil moisture status and depth of irrigation application in the upper soil of 0 – 30 cm which is used by farmers as an indicator of the soil water status and, hence, influences irrigation scheduling decisions.

**Key words:** Depth, irrigation timing, penetration, Tanzania

## **Evaluation of sprinkler irrigation in Simunye Sugar Estate in Swaziland**

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This study evaluated the performance of the sprinkler irrigation system at Simunye in Swaziland. It was observed that there were no available design parameters on which the system of Simunye Sugar Estate was designed. The system showed a uniformity coefficient ( $C_u$ ) of 76%, which was within the recommended  $C_u$  range for design market acceptance. The Distribution Uniformity obtained was 61% and the potential application efficiency for the low-quarter (PELQ) was 54%. Both parameters were lower than the recommended ones of at least 67 and 75 - 85%, respectively. The actual application efficiency for the lower-quarter (AELQ) was 45%, which was too low compared to the PELQ. The minimum basic infiltration rate of the soils irrigated by sprinkler system was  $5 \text{ mm h}^{-1}$ . Factors which contributed to the non-uniformity of the system were wind velocity and wind direction; the operating pressure (which was too high or lower than the recommended one for the system), evaporation losses, and the sprinkler spacing. From the results, it was shown that management of the irrigation system had an effect on the poor performance of the system.

**Key words:** Design market acceptance, evapotranspiration, wind velocity

## **Technical and economic performance of farmer and government managed irrigation schemes in Tanzania**

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This study compared the performance of government-managed irrigation schemes (GMIS) with farmer-managed irrigation schemes (FMIS) at Kapunga Rice Irrigation Project in Mbeya region in Tanzania. The objective was to evaluate organisational structures, water management aspect, productivity and economic performance of the two systems. The farmer-managed scheme performed better than the government-managed in attaining scheme irrigation efficiency, productivity, and economic and financial profitability. Applicable indicators for the farmer-managed irrigation schemes were (i) average productivity,  $3.2 \text{ t ha}^{-1}$  ( $2.2 \text{ t ha}^{-1}$ ); economic profitability: internal rate of return was 3.2% (5%), and benefit/cost ratio 0.6 (0.14). Its financial profitability: Internal rate of return was 3.9% (5.1%), and benefit/cost ratio was 0.6 (0.13). Those of the government managed schema are indicated in brackets. The organisation of both the government and farmer-managed irrigation schemes were appropriate, though both schemes were weak in irrigation management as the essential operation and maintenance activities were not carried out effectively. Both the government and farmer-managed schemes had a canal maintenance problem. There was a corresponding big error in water adequacy of 86% and 98%, respectively arising from improper water control at the secondary canals off-take. Paddy nurseries in the government-managed for operational maintenance, scheme had undesirable water stress. However, both schemes were able to distribute water equitably, reliably, as well as maintaining a correct field water depth from tillering and to flowering and grain formation stages.

**Key words:** Canal maintenance, irrigation efficiency, profitability

## **Use of symbiotic *Azolla-caroliniana* as a water management technique in paddy fields in Tanzania**

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Traditional water management techniques employed in irrigated rice production are deficient, particularly in controlling moisture loss. In this study, *Azolla caroliniana* backed by conventional approaches, e.g., soil puddling, sub-soil compaction and levee coating reinforced with lateral flow barriers, was used to suppress evapotranspiration in rice fields under irrigation. A field experiment was carried out at Lower Moshi Irrigation Project in Kilimanjaro region in Tanzania between the dry season and short rainy season (2000-2001). A local indigenous variety known as Wahiwahi was used. Treatments included: Wahiwahi only (T1); Wahiwahi and Azolla (T2) and Azolla only (T3). Ridges were made around the individual plots to allow ponding. Azolla was administered in treatments T2 and T3, 7 days after transplanting. Crop water use measurements were done at 14 days post-transplanting and, thereafter, daily for the whole growing period (three and half months). One lysimeter and one percolation cylinder were installed in each treatment to facilitate the measurements. Total water use obtained in treatments T2 and T3 was 8.13 and 7.05 mm day<sup>-1</sup>, respectively; which were not significantly different ( $p>0.05$ ). In treatment T1, total water use was 11.99 mm day<sup>-1</sup>, which was significantly higher ( $p<0.05$ ) than in T2 and T3. There was no significant effect ( $p>0.05$ ) of Azolla on seepage and percolation. The lowest evapotranspiration was obtained in treatment T3, with a value of 2.24 mm day<sup>-1</sup>; which was significantly different ( $p<0.05$ ) from T1 and T2. Evapotranspiration was 6.48 mm day<sup>-1</sup> in treatment T2, which was 23% lower and significantly different ( $p<0.05$ ) from that in T1. Reduced dry matter weight of weeds was registered in T2 and T3, where the weed control efficiency was significantly higher ( $<0.05$ ) than T1. Rice plant growth in T2 was greater and more superior throughout the growing period compared to plants in T1. Grain yield in T2 was 7.93 t ha<sup>-1</sup>, which was significantly higher ( $<0.05$ ) than 6.31 t ha<sup>-1</sup> in T1. Azolla management gave soil-moisture retentivity of 32% that resulted in increased water use efficiency by the crop. Use of *Azolla caroliniana* in irrigated rice cultivation is recommended as a water management practice.

**Key words:** Rice, ridges, soil moisture, weeds

## **Evaluation of irrigation schedules under traditional farmer managed irrigation system in Tanzania**

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This study was conducted at Herman Canal Irrigation Scheme to evaluate the real time, the climatic data based and farmer managed irrigation schedules under traditional farmer-managed irrigation conditions; and assesses their rationale with a view to improving water use efficiency. The mean total water delivery in farmer-managed plot was 735 mm, which was generally more than adequate for a bean crop. Relative water supply ranged from 1.12 to 2.64, with a mean of 1.68. The mean values of timely and surplus were 0.85 and 0.83, respectively. Throughout the growing season, more than sufficient water was applied for the shallow rooted bean plant and the moisture content was kept well above the critical content. Farmers lacked basic

understanding of irrigation scheduling and irrigation management. Lack of technical know-how and poor water users' organisation was the major cause of low performance in farmer managed schedule. There were significant ( $p < 0.05$ ) differences in irrigation water productivity (IWP) and field application efficiency (FAE) between treatments. The FAE and IWP of farmer-managed schedule were significantly ( $p < 0.05$ ) lower than all other treatments, but the FAE of the control plot and climatic data plot was not significantly different. Irrigation water productivity was highest in the control plot, followed by the climatic data based plot and the farmer-managed schedule. There was no significant ( $p < 0.05$ ) difference in physiological water use efficiency (PWUE). Land productivity values for the climatic data based schedule were significantly higher than the other methods, but the yield between the control plot and farmer-managed plot was not significantly different. The low performance of the conventional farmer-managed scheduling methods in the area indicates need for improvement in water management strategies, and gives an impression that there is a potential to concomitantly improve both water and land productivity.

**Key words:** Climatic data, Herman canal, water use efficiency

### **Regulated deficit irrigation as a water management strategy in semi-arid areas in Tanzania**

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This study was conducted at Herman Canal Irrigation Scheme in Tanzania to evaluate the efficacy of Regulated Deficit Irrigation (RDI) as a water management strategy for field crops in smallholder irrigation schemes under semi-arid conditions. There were five irrigation treatments, namely: a farmer irrigated, a control, and three RDI treatments. Water productivity (WP) varied spatially, with the lowest WP in the head block. Among the treatments, the highest WP ( $1.10 \text{ kg m}^{-3}$  and Tanzania Shillings  $883 \text{ m}^{-3}$ ) was found in RDI at 50% soil moisture depletion that also saved 10% irrigation water with 3% yield reduction. From the current non-volumetric water pricing system in the scheme, irrigation depths by the farmers produced the lowest WP ( $0.44 \text{ kg m}^{-3}$  and Tsh  $348 \text{ m}^{-3}$ ), although profits were highest. However, RDI at 50% soil moisture depletion maximised WP and profits more than the farmer-irrigated treatment assuming a volumetric water pricing system. The yield response factor for the whole scheme ( $\epsilon_y = 0.50$ ) suggests that the bean crop was not very sensitive to RDI. However, the crop was more sensitive to RDI in the Head ( $\epsilon_y = 1.07$ ) than in the Middle ( $\epsilon_y = 0.35$ ) and Tail ( $\epsilon_y = 0.33$ ) blocks. The number of seeds per pod was unaffected by water deficits, while both the number of pods per plant and 100 seeds weight were reduced by water deficit. Higher correlations with grain yield were obtained between 100 seeds weight ( $r = 0.95$ ) and the number of pods per plant ( $r = 0.91$ ), compared with the number of seeds per pod ( $r = 0.89$ ). WP and profits can increase in the Scheme if RDI with moderate deficits could be adopted, especially when water is charged on actual applied volume.

**Key words:** Farmer-irrigated, non-volumetric water pricing

### **Sustainability of irrigation schemes for small scale farmers of furrow irrigation schemes in Zambia**

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This study was carried out to determine factors that influence sustainability of smallholder irrigation schemes in Zambia. This was against the background that many schemes have been opened by the government to resettle people and have operated smoothly under its management. But upon government withdrawal, farmers have failed to manage these schemes. The study was carried out at Buleya Malima Smallholder Irrigation Scheme, in Zambia. Results showed technical data in the order of 26.4, 64.5 and 9.2 for application efficiency, trailwater ratio, and deep percolation ratio respectively. There was a waste of water by farmers through tailwater runoff. Thus, the system performed poorly, and could not be sustained at the prevailing levels of water loss. It was also clear that irrigated farming could be sustainable if properly designed and planned with the involvement of the farmers. The big problem was lack of managerial ability and innovativeness by the scheme management to provide farmers with enabling environment to form their own viable organisations, which could promote the continuity of the scheme after government withdrawal. Formal and informal training in technical operations of irrigation infrastructure and new agricultural practices should be provided, so that farmers are able to operate the irrigation system with minimum dependence on management.

**Key words:** Application efficiency, trailwater ratio, water loss

### **Effect of irrigation water on infiltration rate and saturated hydraulic conductivity in irrigation schemes in Tanzania**

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A study was conducted at Ruaha Mbuyuni Farmers' Managed Irrigation Scheme in Iringa region in Tanzania, to assess the effect of irrigation water on infiltration rate and hydraulic conductivity and onion crop performance. The study involved assessment of water quality and soil properties in relation to infiltration rate and hydraulic conductivity problems, crop (onion) water requirement at different stages and its performance under different soil types. Water from Lukosi River was saline but had low sodium water. Chemically, this water had a slight effect on infiltration rate and hydraulic conductivity. The concentrations of suspended sediments were high and about 25.54 t ha<sup>-1</sup> – 42.15 t ha<sup>-1</sup> of sediment were deposited in the fields over the season. This resulted into sealing and clogging of soil pores, hence, reducing infiltration and hydraulic conductivity. Soil texture in the scheme ranged between sandy loam to heavy cracking clays, which were neither saline nor sodic. The soils were slightly alkaline with pH ranging from 7.4 to 7.8. The organic matter content were generally very low, ranging from 1.13 to 3.05%. Due to low organic matter content, the soils had poor structural stability and, hence, were easily dispersed by water. Dispersion effects resulted in reduction in infiltration rate and hydraulic conductivity. Soil basic infiltration rate ranged from 3.75 to 2.5 mm h<sup>-1</sup>, while saturated hydraulic conductivity ranged from 0.031 to 0.42 m d<sup>-1</sup> for clay and sandy loam soils, respectively. Basic infiltration rate decreased for an average of 50%, while hydraulic conductivity decreased for an average of 52-58% over the season in all soils. High

deposition of sediment and high dispersion effect of irrigation water on the soils were the main reasons for decreased infiltration rate and hydraulic conductivity over the season. Crop (onion) performance was generally low in all locations compared to the normal yield of 35-45 t ha<sup>-1</sup> and 8-10 kg m<sup>-3</sup> for yield per unit area and specific yield, respectively. Medium textured soils which had moderate infiltration and hydraulic conductivity had better yield of 31.5 t ha<sup>-1</sup>, while coarse texture soils with rapid infiltration showed very poor yield of 13.3 t ha<sup>-1</sup>. Clay soils had better specific yield (5 kg m<sup>-3</sup>), while sand soils showed low specific yield of 3 kg m<sup>-3</sup>. Low infiltration rates and hydraulic conductivity resulted in water logging problems in the heavy textured soils. Rapid infiltration in the coarse textured soils caused water stress to crops and drain of plant nutrient below root zone which contributed to low yields. Water application depended on the available irrigation water and not on crop water requirement. Relative water supply ranged from 0.92 to 5.36 per crop development stage. Irrigation intervals, which were far spaced, were the main reason for excess water application during irrigation.

**Key words:** Cracking clays, organic matter, saline, sordic

### **Modeling of field-to-field irrigation method in paddy basins for efficient water management**

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In rice fields, the most common traditional irrigation method is field-to-field irrigation, i.e. conveyance of water across a paddy basin through a simple weir or circular pipe to irrigate the next basin. In using the method, there is uncertainty as to when the *n*th basin in a cascade, will receive the water after the preceding basins have attained the required depths. The study, to model field-to-field irrigation method in paddy was conducted at Kasitu Self-help Irrigation Scheme in Malawi. This system of irrigation is practiced at this scheme. A Reservoir Routing Equation was adopted and used to develop irrigation water routing model for paddy basins in field-to-field irrigation method by incorporating the factors associated with paddy basins. The model showed high precision in predicting paddy basin water storage with given inflows and outflows in a specified time. Hence, it was able to predict closely the time of fill of a given depth in a paddy basin. Results from the observed and calculated changes in water storage (in depth units) showed no significant difference in 11 sets out of 15 sets of data. The factors which affect water storage in a paddy basin and, hence, time of fill included the initial soil water content, surface water inflow, surface water outflow, vertical seepage and percolation through the basin base, horizontal seepage across the bunds with water loss through cracks and fissures, evapotranspiration and rainfall. The time of fill of *n* basins in a cascade of paddy basins was obtained as the summation of times of fill of each of the *n* basins. The distance of travel of the stream flow was taken as the summation of the longitudinal distances of each basin in the direction of flow to the water front. Basin storage, time of fill, and distance travelled by the water front were all dependent on stream size (inflow and outflow), basin size and the associated water losses. The study proved that water travel time and time of fill of a paddy basin is predictable by using the factors which affect water storage in paddy basins.

**Key words:** Basin storage, evapotranspiration, rice

### **Evaluation of furrow irrigation system at Simunye Sugar Estate in Swaziland**

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This study evaluated the performance of the furrow irrigation system at Simunye Sugar Estate in Swaziland. The objectives were to: (a) identify original design parameters, (b) evaluate performance of the system design, and (c) identify management practices and system configurations that could improve the irrigation efficiency. Results showed that there had been some changes in the design parameter mentioned in the Irrigation and *Maintenance Manual* for Simunye. It was clear that there was 21 and 40% increase in gross water application and slope, respectively. Application efficiency and furrow length had decreased by 12.4 and 23%, respectively. Other design parameters were not available at the Estate. The system showed acceptable values of deep percolation losses (9%) and distribution uniformity (95.1%). However, the application efficiency (65.7%), tailwater runoff (25.3%), and water requirement efficiency (65.7%) were all outside the recommended ranges. Factors which led to the decreased application efficiency were the high tailwater runoff, high advance trajectory rates ( $11.4 \text{ tx}^{0.78}$ ), and large furrow inflow discharges ( $0.215 \text{ m}^3 \text{ min}$ ). From the results, it was recommended that flow measuring devices (e.g. flumes) should be installed at the beginning of tertiary canals. The cutback method should also be introduced.

**Key words:** Application efficiency, furrow length, runoff

### **Landcover dynamics and hydrological functioning of wetlands in Uusangu plains in Tanzania**

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In the Usangu Plains of the Upper Great Ruaha River Catchment in Tanzania, the hydrology of the wetlands and the downstream flow regime changes in response to changes in land use and cover was investigated through analysis of remotely sensed images and modeling. A hydrological model for the eastern wetland that accounts for the water balance was developed. This model was used to evaluate the hydrology of the eastern wetland in response to changes in land use and cover and the amount of inflows into the eastern wetland required to maintain a specified outflow downstream of the wetland. A small wetland locally called *Ifushiro*, located in the upstream of the eastern wetland in response to changes in land use and cover and the amount of inflows into the eastern wetland required to maintain a specified outflow downstream of the wetland. A small wetland locally called *Ifushiro* located in the upstream of the eastern wetland was also investigated to evaluate its contribution to dry season flows. The analysis involved a detailed hydrometric monitoring and modeling using Visual MODFLOW software. The *Ifushiro* wetland was modulated by the changes in land use and cover on the upstream. Since 1958, increased diversion of water caused average dry season inflows to the eastern wetland to decrease from approximately  $15.0$  to  $4.3 \text{ m}^3 \text{ s}^{-1}$ . This has led to a reduction in the average minimum dry season surface area of the wetland from approximately  $160$  to  $93 \text{ km}^2$ . Since the early the 1990s, the decrease in dry season water-levels within the wetland has resulted in prolonged periods of zero flow in the Great Ruaha River, with severe consequences

for the ecology of the Ruaha National Park. The wetland model enabled calculation of the inflows required to maintain specified discharges. To maintain a flow of  $0.5 \text{ m}^3\text{s}^{-1}$  as the minimum required flow for maintenance of fish habitat and the current ecology of the Park, required an average dry season inflow of approximately  $7.0 \text{ m}^3\text{s}^{-1}$  into the eastern wetland in the dry season. The results from this research demonstrate the value of combining different research methods/approaches and the use of simple models to examine system functioning to assist decision-making.

**Key words:** Fish habitat, modelling, visual mode flow

### **Effective length of growing season in Tanzania**

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The study was based on 15 stations in Tanzania to determine the start, the end and the length of effective growing season. Weather data of duration ranging from 30 to 37 years were collected and two criteria were used to define the events of interest; the first criterion based purely on rainfall, while the second utilised both rainfall and evapotranspiration. Significant variability in the start and end dates was evident in almost all stations. The start and end dates of the effective growing season, had no discernible trend both in time and space. It was further noted that the rainfall and evapotranspiration criterion is not sufficient to define the end of the growing season. Knowledge of soil-water storage is required to define this event more realistically. Stations which appeared to have longer growing season like Shinyanga, Mpwapwa, Maswa and Lindi; had very poor rainfall distribution and very high probabilities of dry spells within the growing season. Supplemental irrigation, water conservation or water harvesting practices are, thus, the possible solutions for sustainable crop production these areas. As a recommendation, the use of crop growth simulation models, alongside packages like INSTAT to define the characteristics of the effective growing season more realistically, seems to be more appropriate.

**Keywords:** Evapotranspiration, rainfall, soil water, weather

### **Spatial environmental assessment of the impact of land use on land resources in Siavonga District, Zambia**

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The construction of the Kariba Dam between 1955 and 1959 necessitated that 57,000 Tonga speaking people of the Zambezi basin had to be moved to the surrounding areas on both sides of Zambia and Zimbabwe. This study assessed the implication of the resettlement of up to 6,000 Tonga speaking people into Lusitu area, Siavonga District of Zambia. Aerial photo interpretation (API) for the year 1970 in conjunction with Landsat TM images for the years 1986 and 1995 were used. The pattern and rate of deforestation, settlement pattern, human population dynamics and density, livestock population, educational and technological level as well as government level as well as government policy on land status as possible causes or

influencing factors of spatial and temporal land resource degradation were examined. Results revealed that two different processes contributed to land resources degradation namely; (a) conversion of most of the available forests in all categories and other forms of vegetation from higher grades to lower grades; and (b) lack of comprehensive reforestation programmes. It also revealed that the annual deforestation rate in Lusitu area from 1970 to 1995 was 483.28 ha  $y^{-1}$  (2.0%  $y^{-1}$ ). Between 1970 and 1986, it was 366.4 ha  $y^{-1}$  (1.55%  $y^{-1}$ ), while for the period 1986 to 1995 the deforestation rate was 691.0 ha  $y^{-1}$ . There was an increasing rate of deforestation in Lusitu from 1986 to 1995 compared with 1970 to 1986. In Siavonga district, between 1986 and 1985, the rate of deforestation was 3772.8 ha  $y^{-1}$  (2.2%  $y^{-1}$ ). Comparing the deforestation rates for the temporal periods for Lusiku and Siavonga, the deforestation rate for Lusitu area for the period 1986 and 1995 was higher than for the entire Siavonga District, while for the period 1970 to 1986, it was lower than that for Siavonga District. A general trend of increase in cultivated areas was noted; a trend in the evolution of bad land was identified. A spatial pattern of deforestation appeared to be related to the settlement distribution pattern. The increase in human and livestock population explained part of the rate of deforestation in particular as well as land degradation in general. A general trend in cultivation of hilly areas and close to river banks was noted. Desertification conditions were also observed at the confluence of Zambezi and Lusitu

**Keywords:** Deforestation, resource degradation, Tonga, Zambia

### **Determination of humidity-referenced potential areas for crop production in Tanzania**

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This study sought to determine the potential areas for production of maize, sorghum, groundnuts and beans based on humidity levels. Rainfall and evapotranspiration data of 97 stations were collected from the Directorate of Meteorology, while the maximum water holding capacity, the growing periods and the crop coefficients of the selected crops were estimated from those available in the literature. Data analysis was based on hydrologic budget balancing model for stations. Potential areas were delimited by grouping of stations of the same humidity levels. The areas were then compared with those under current production. The study found that the approach seemed to provide basic information on potentials and could, therefore, be used for agricultural planning purposes. A fairly large percentage of areas established through this method, especially for maize and sorghum, coincided with the current production areas. Among the three crops, beans showed the greatest potential over the country's total area and only 20% of it was utilised, while groundnuts had the highest percentage of its potential area being unutilised.

**Key words:** Evapotranspiration, groundnut, hydrologic budget, maize, rainfall

## **Land use patterns in Morogoro and Kikundi river catchments in Tanzania**

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The Morogoro and Kikundi River Catchments of Tanzania's Uluguru Mountains occupies about 2300 ha at 550 to 2,000 metres above sea level. Mean annual rainfall ranges from 800 to >1500 mm, while mean annual temperature ranges from 25 to 19°C. A grid of 100 m<sup>2</sup> sample units located at intervals of 150 m (north-south) and 500 m (east-west), was surveyed for environmental and crop information. Data were assembled from 165 units. More general environmental information on physical, geological and climatic features was extracted from literature. Complementary socio-economic data were acquired through interviews with 67 farmers from the area. Farmlands (68% of the catchments) were the main land use, extending to steep (>30% slopes) and was associated with sheet erosion against, for which minimal control was done. Four major land use units could usefully be recognised; namely, water source areas, woodland, upper catchment and lower catchment. The woodland areas, in the lower part of the catchment, were viewed as potential fuel source under appropriate management. Agricultural activity should be restricted to the upper (wet) and lower (dry) catchments, and be planned taking into account slope categories. There was concern among the farmers about low crop production levels and there was no evidence of contact with effective agriculture and forestry extension programmes. Despite emphasis on quantification and interpretation of the existing situation on the catchments, and the Land Classification and Land Evaluation steps in the Land Use Planning process, it was possible to draw conclusions about constructive future activities on the respective land use units identified through the study. The most important of these for the immediate future were: that cultivation should be restricted to gentle (0-15%) slopes (especially maize) and moderate (15-30%) slopes (especially banana). Where use of the steeper slopes was unavoidable, growing of coffee would be preferred. In all cases, more attention needs to be put to the active application of soil conservation measures.

**Key words:** Banana, erosion, maize, sheet, woodlands

## **Effect of forest types on water input in mindu forest reserve at Morogoro in Tanzania**

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Effect of selected sites of miombo woodland and dry semi-evergreen forest on water input in an open area was evaluated based on hydrological processes. A 0.1 ha plot was set up in either vegetation to investigate the rainfall redistribution in terms of interception, net rainfall, comprising of through fall and stem flow, and surface runoff. Significantly greater net rainfall was observed in the woodland (95.3 % of gross rainfall, G.R) than in the forest (78.9% of G.R.). Overall, the woodland yielded significantly more water (i.e. net rainfall) per given rainfall incident than the forest. Loss of part of the incident rainfall through interception was 21 and 5% of G.R. for the forest and the woodland, respectively. Being highly significant, such a difference makes the woodland of greater benefit for water intake in catchment areas than the forest. However, loss of water through surface rainfall was significantly greater in the woodland (2.7% of G.R.) than in the forest (1.1% of G.R.). Inversely, the forest showed consistently higher

soil moisture levels than the woodland, indicating a possibly greater capability of conserving water over a long period of time, though this can only be implied as the differences were not significant and as field capacity and wilting point of the soils were not determined. The microclimatic conditions modified by the particular vegetation type are associated with its water preservation value. The miombo woodland and the dry semi-evergreen forest had significantly higher relative humidity and less evaporation. This study confirmed interception, net rainfall and surface runoff as the major determining factors of the effect of vegetation types on the water input.

**Key words:** Forest, Miombo woodlands, rainfall, soil moisture

### **Control of nitrogen mineralisation from decomposing *Gliricidia sepium* leaves for optimise nitrogen uptake by maize crop**

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Decomposition (mass loss) and mineralisation studies were conducted at Kitete village, in Tanzania to control the rates of decomposition and nitrogen release from *G. sepium* (Jaq) Walp leaves through widening their C/N ratios. Litter bags containing 150 g of *G. sepium* leaves (and variable amounts of sawdust (0, 25, 50, 75 and 100%) of fixed *G. sepium* were used in the decomposition experiment. Different rates of *G. sepium* leaf rates (1.5, 1.15, 0.76 and 0.38 kg dry leaves plots of 60, 45.30 and 15 kg N ha<sup>-1</sup>) and various *G. sepium* and sawdust mixtures containing a fixed amount of leaves (1.5 kg plot<sup>-1</sup>) and variable amounts of sawdust were used in the mineralisation experiments conducted and maize farm. mineralisation Treatment with *G. sepium* alone significantly ( $p=0.002$ ) higher mass loss and nitrogen release but decreased with increasing C/N ratio in *G. sepium* sawdust mixtures. Rates of mass loss were influenced by placement depth. Most of the N from *G. sepium* alone was released within 6 weeks. Nitrate N dominated the mineral N, ranging from 67 to 80%. The N uptake by maize plants, maize height increment and maize crop yields were significantly higher in plots with correspondingly highest C/N ratios. Also, there were positive correlations between nitrogen uptake and maize growth ( $r = 0.76$ ) and maize yield ( $r = 0.858$ ). A 3-8 weeks period is a critical for high nutrients demand by maize crop in the study area.

**Key words:** C/N ration, maize, nitrogen release, sawdust

### **Nitrogen mineralisation *Prosopis chilensis* and maize yield from a fallow of *Prosopis chilensis* in Tanzania**

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This study was conducted to assess the effect of three-year old fallow of *Prosopis chilensis* (Molina stuntz) on general soil properties, nitrogen mineralisation and maize yield on an ongoing agroforestry experiment at Gairo in Morogoro, Tanzania. Three treatments; trees alone (T), maize (M) alone and trees plus maize (T + M) were considered. Trees alone treatment had higher level of K<sup>+</sup> (1.0 cmol kg<sup>-1</sup>) than other treatments which had the lowest level (0.7 cmol K<sup>+</sup>

kg<sup>-1</sup>). Magnesium differed significantly among treatments, with the maize alone having the highest level (2.0 cmol kg<sup>-1</sup>) and the treatment with trees alone having the least (1.6 kg<sup>-1</sup>). Total P differed significantly ( $p < 0.05$ ) between treatments with the trees alone having the highest total P (229.6  $\mu\text{g g}^{-1}$ ), and maize alone having lowest value (159 ppm). Total N and available P decreased significantly ( $p < 0.05$ ) with soil depth. In contrast Mg<sup>2+</sup> and Ca<sup>2+</sup> were higher in the subsoil than in the top soil.

**Key words:** Calcium, magnesium, maize, phosphorus, trees

### **Effect of relay intercropping of *Sesbania sesban* on soil fertility and firewood production at Mafiga in Tanzania**

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This study was carried out at Sokoine University of Agriculture farm in Morogoro, Tanzania to examine the effect of relay intercropping of *Sesbania sesban* and maize on soil fertility and production of maize and firewood. An existing one year relay intercropping experiment in which *S. sesban* was allowed to grow after harvesting of maize during the dry season was studied. Firewood biomass after 1 year of intercropping was 3 t ha<sup>-1</sup>. Maize was intercropped with and without *S. sesban* at 0, 20, and 40 kg ha<sup>-1</sup> each of nitrogen and phosphorus. Intercropping increased soil mineral N status slightly. Maize grain yield was significantly ( $p < 0.05$ ) higher in *S. sesban* plots without fertiliser (2.43 t ha<sup>-1</sup>) compared to the control (2.09 t ha<sup>-1</sup>). The three levels of N and treatment interaction effects had no significant ( $p > 0.05$ ) effect on maize yield. In contrast, the three levels of P differed significantly ( $p < 0.05$ ) for their effects on maize grain and stover yields. Maize grain yield from plots of 20 kg P ha<sup>-1</sup> was 2.39 t ha<sup>-1</sup> and 40 kg P ha<sup>-1</sup> was 2.36 t ha<sup>-1</sup> compared with the control (2.02 t ha<sup>-1</sup>). In order to determine decomposition rate and nutrient release of selected species, a 10 week decomposition experiment involving litter bags containing green manure from *Albizia lebeck*, *Gliricidia sepium*, *Senna siamea*, *Sesbania sesban* and *Tephrosia vogelii* was also studied. Significant ( $p < 0.05$ ) differences existed in decomposition in order *Gliricidia sepium* > *Sesbania sesban* > *Albizia lebeck* = *Senna siamea* > *Tephrosia vogelii*; N release in the order ( $p < 0.01$ ) *Sesbania sesban* > *Gliricidia sepium* > *Tephrosia sepium* > *Albizia lebeck* > *Senna siamea* > *Gliricidia sepium* > *Sesbania sesban* > and phosphorus release in the order ( $p < 0.01$ ) *Tephrosia vogelii* > *Gliricidia sepium* > *Sesbania sesban* > *Senna siamea* > *Albizia lebeck*. Nitrogen and phosphorus release ranged between 128 - 202 kg N ha<sup>-1</sup> and 7.76 - 12.88 kg P ha<sup>-1</sup>. Most of the N and P were released within the first four weeks of decomposition. Based on these results, *Sesbania sesban*, *Gliricidia sepium* and *Tephrosia vogelii* showed greatest potential for use as green manure; and relay intercropping of *Sesbania sesban* and maize has potential in increasing maize yield even without fertilisers.

**Key words:** *Gliricidia sepium*, *Senna siamea*, *Tephrosia vogelii*

### **Effects of forest plantations on soil properties at Sao hill forest plantations in Tanzania**

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A study was designed to compare selected soil properties under natural *Brachystegia* miombo grassland and vegetation and adjacent young and old plantations of *Pinus patula* Scheld & Cham and *Eucalyptus saligna* at Sao Hill forest Plantations. Soil samples were collected from paired plots in natural vegetation and adjacent plantations. All soil physical properties except soil moisture content (MC) and bulk density (BD) at 0-5 cm depths did not differ significantly ( $p < 0.05$ ) compared with their adjoining natural vegetation. Overall, MC was lower in old stands of pine than in young stands. Soil bulk density was higher under pine plantations but decreased under *Eucalyptus* plantations. Soil EC, pH, Total N, P and OC did not differ significantly ( $p > 0.05$ ) for all soil depths under the study conditions. Organic carbon and available P increased in most soil depths under all stands of both plantation species, but available P increased significantly ( $p < 0.05$ ) at 0-5 cm and 5-10 cm soil depths under old *Eucalyptus*. Nitrate N was significantly ( $p < 0.05$ ) lower at 0-5 cm depth under young pine and at 0-5 cm depth under young *Eucalyptus*, while N was significantly higher under older pine at 0-5 cm soil depths.

**Key words:** *Brachystegia* spp., *Eucalyptus saligna*, Miombo grassland, *Pinus patula*

### **Effect of improved fallows of leguminous shrubs soil fertility and maize yield in Morogoro, Tanzania**

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A study to evaluate the effect of improved fallows and nitrogen and phosphorus fertilisation on soil fertility was carried out at Gairo, a semi-arid area in Morogoro, Tanzania. Treatments included fallow type (*Cajanus cajan* (L) Millsp, *Gliricidia sepium* (Jac Q) Walp, and included *Sesbania macrantha* Phil and Hultch, *Sesbania sesban* (L); others natural fallow) and the minor factor was nitrogen and phosphorus fertilisation (0 N and 0 P kg ha<sup>-1</sup>, 20 N and 15 P kg ha<sup>-1</sup>, 40 N and 30 P kg ha<sup>-1</sup> and 80 N and 60 P kg ha<sup>-1</sup>). Wood biomass was significantly ( $p < 0.05$ ) among different shrubs with the highest value 19.20 t ha<sup>-1</sup> for *S. sesban* and least 6.57 t ha<sup>-1</sup> *C. cajan*. Foliar biomass was between 1.63 t ha<sup>-1</sup> (*C. cajan*) and 7.34 t ha<sup>-1</sup> (*G. sepium*). *Gliricidia sepium* fallow enhanced soil fertility better than other fallows. The soil electrical conductivity ranged from 0.07 dSm<sup>-1</sup> for natural fallow to 0.29 dSm<sup>-1</sup> for *G. sepium*; and organic carbon 0.76% (natural fallow) to 2.59% (*G. sepium*). Available P ranged from 2.07 mg kg<sup>-1</sup> (natural fallow) to 32.46 mg kg<sup>-1</sup> (*G. sepium*), CEC 5.33 cmol kg<sup>-1</sup> (Natural fallow) to 8.87 cmol (+) kg<sup>-1</sup> (*Gliricidia sepium*). The natural fallow resulted in maize grain yield of 3.66 t ha<sup>-1</sup>, followed by *S. sesban* 1.9 t ha<sup>-1</sup> and least natural fallow (1.56 t ha<sup>-1</sup>). Stover yield was between 3.51 t ha<sup>-1</sup> (*G. sepium*) and 1.2 t ha<sup>-1</sup> (Natural fallow). Also, in fallow plots which received N and P fertilisers tended to increase maize leaf unit mat leaf, maize grain and stover N and P concentrations and content when N and P fertiliser were applied.

**Key words:** *Cajanus cajan*, *Gliricidia sepium*, *Sesbania sesban*

### **Synchronisation of nutrient release from *Gliricidia sepium* mulches for maize at Sua farm in Morogoro, Tanzania**

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This study was conducted at Morogoro, Tanzania, to assess the effect of synchronised mulching of *Gliricidia sepium* on soil nutrient status; nutrient uptake by maize and field performance of maize. Treatments were as follows: major factor (mulch application dates) i.e. just before sowing (T1) two weeks after sowing (T2), four weeks after sowing (T3), 6 weeks after sowing (T4). Minor factor (Mulch application rates) i.e. control (0 kg ha<sup>-1</sup> and 8 kg plot ha<sup>-1</sup> M3) and 10.0 t ha<sup>-1</sup> (1000 kg ha<sup>-1</sup>), 16 kg plot ha<sup>-1</sup> M4). Nitrogen mineralisation at all sampling periods showed significant differences (p<0.05) between mulching site treatments except at weeks 1 and 4 for nitrate-N and at weeks 1 and 2 for ammonium-N. Nitrogen mineralisation was not affected by the time of mulching application. Nitrate dominated the system throughout. Maize yield was not significantly (p>0.05) affected by time of mulching, grain and stover, but was significantly affected by mulch rates. Mulching time had no significant effect on maize growth and yield; however, it was significant on grain P and stover N uptake.

**Key words:** Ammonium, mulching, nitrate, nutrient uptake

### **Effects of fallow periods of legumes on soil fertility and maize and firewood production at Gairo in Morogoro, Tanzania**

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This study was carried out at Gairo to evaluate the effects of fallow periods and types, and N and P fertilisation on soil fertility improvement, maize growth and yield and firewood production. Treatments included fallow period (1, 2, 3 year fallows); fallow type (*Sesbania sesban* (L) merril, *Tephrosia vogelii* (f) hook, *Cajanus cajan* (L) Millsp; and fertiliser (0 kg N and 0 kg P ha<sup>-1</sup>; 0 kg P and 40 kg N ha<sup>-1</sup>; 0 kg N and 40 kg P ha<sup>-1</sup>; 40 kg N and 40 kg P ha<sup>-1</sup>). Tree/shrub species differed significantly (p<0.05) in total biomass production, with *C. cajan* out-ranking others in 1 year fallow i.e. 10 t ha<sup>-1</sup> and the least value coming from *T. vogelii* (5.44 t ha<sup>-1</sup>). In 2-year fallow, *S. sesban* was outstanding (69.84 t ha<sup>-1</sup>) and the lowest value was achieved with *C. Cajan* (6.79 t ha<sup>-1</sup>); wThe 3-year fallow, *S. sesban* was still outstanding (46.02 t ha<sup>-1</sup>) and the lowest value was from *C. cajan* (8.25 t ha<sup>-1</sup>). Shrub wood and foliage N and P concentrations also differed significantly, with fallow period and shrub species. Wood N concentration from 2 year fallow of *S. sesban* was the highest (1.08%), while the lowest value in 2 year fallow was from *T. vogelii* (0.95%). In wood P concentration, 2-year fallow *T. vogelii* out-ranked the other shrub species. (0.136%) and the lowest value in 2-year fallows came from *C. cajan* (0.31%). For foliage N concentration, the 2-year fallow of *S. sesban* was outstanding (2.94%) and the least foliage N concentration value 2-years fallows was from *C. cajan* (2.52%). Greater improvement in soil fertility was achieved by *S. sesban*. Soil electrical conductivity ranged from 0.0 dSm<sup>-1</sup> for a 3 year natural fallow to 0.21 d Sm<sup>-1</sup> for a 3 year *S. sesban* fallow.

**Key words:** *Cajanus cajan*, nitrogen, phosphorus, tree shrub

## **Effect of forest management systems on soil conditions of Kitulanghalo Areas in Tanzania**

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A study was carried out at Kitulanghalo Morogoro, Tanzania to investigate the effect of three forest management systems on soil conditions. The forest management systems were private, state and public lands. The major soil groups were haply-chromic phaezems (typic haplustolls) in the state forest, haplichromic lixisols (typic haplustaffs) in the private forest, Rdo-d-profondic lixisols (typic phodustalts) and chromi-profondic lixisols (typic haplustafs) in the public land. Each management system was sampled at 4 depths on summits, slopes and valley bottoms for laboratory physical chemical analyses. The public Lands forest management system led to drastic changes in soil properties. It had an altered texture with a significantly high content of sand and significantly low clay and silt content ( $p < 0.05$ ). Soil bulk density was significantly high ( $p < 0.05$ ) and total porosity and volumetric water content were significantly low ( $p < 0.05$ ). It had significantly lower available water capacity compared to the private forest ( $p < 0.05$ ). The organic carbon, total N, C/N ratio available P, CEC, exchangeable calcium, magnesium, and sodium, total exchangeable bases and percent base saturation were significantly lower ( $p < 0.05$ ) in this forest management system. The population of soil fauna in the public land management system was also significantly lower ( $p < 0.05$ ) than either the private or state forest management system. The public forest management system had significantly higher ( $p < 0.05$ ) available water capacity, organic carbon and available phosphorus in the 0-15 cm depth and also soil fauna compared with the State forest system. The valley bottoms under private and state forest systems had severe and mild depositions of soil, respectively, from summits and slopes due to erosion.

**Key words:** bulk density, fauna, phosphorus, porosity

## **Farmers' utility of irrigation water supply as a method of assessing irrigation system's performance**

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Models which employ Farmers' Utility of Irrigation Water Supply (FUIWS) in assessing irrigation system's performance were developed in this study. The methodology was tested at Lower Moshi Farmer Managed Irrigation Scheme (Lower Moshi FMIS). The objective was to investigate FUIWS as a method of assessing the performance of irrigation systems. A non-linear but significant correlation was observed between Relative Water Supply (RWS) and FUIWS.  $R = ae^{nU}$ ; where  $R = RWS$  in paddy field,  $U = FULWS$ , with "a" and "n" being consonants. In this particular study, the scheme model obtained was:  $R = 0.377e^{1.825U}$ . Similar block models were established. The homogeneity test on the block mean values showed that RWS had the same degree of variability for all levels of FUIWS. This indicated the ability of the scheme model to be used in place of block models. Different "a" and "n" consonant values obtained between blocks indicated different irrigation management levels between blocks. This model was, however, tested in paddy rice only. More work is, therefore, needed to test it

in upland crops. It is also necessary to establish whether threshold values “a” and “n” are universal and what factors influence them.

**Key words:** Irrigation management, modelling, water use

### **Sprinkler performance evaluation at Mtibwa Sugar Estates in Tanzania**

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Irrigated agriculture is known to be very productive because water, which is in most cases is the most limiting, is applied to crops in the right quantities and at the right time. This, however, is only true if the supply system is performing as recommended. In Mtibwa Sugar Estates, Morogoro, Tanzania, sugarcane is produced under sprinkler irrigation, unfortunately, cane yield on this estate does not differ significantly from that on rainfed field. A performance evaluation aimed at evaluating Mtibwa sprinkler irrigation system was therefore carried out. About 20% of all sprinkler irrigated blocks had a coefficient of uniformity below 80%. The pressure ranged from 1.8 to 3.2 bar, with 73% of all blocks having sprinklers operating below the designed pressure of 3.2 bar. About 38% of all blocks required longer duration of irrigation than the current practice for the right amount of water to be supplied. The longer required irrigation duration was a result of the application rate caused by low pump operating pressure and consequently low pressure at the sprinklers.

**Key words:** Coefficient of uniformity, irrigation, sugarcane

### **Performance of proportioning water-division devices: A case study of Njoro ya Goa in Tanzania**

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This study aimed at assessing the performance of proportioning water-division devices in Farmer-Managed Irrigation systems (FMIS) at Njoro ya Goa in Tanzania. The performance of these devices was evaluated in Canal I (Goa I), Goa 2 was used to evaluate the performance of the existing mud-and-stones water diversion technique. For Goa 1, the difference between the measured and expected flows was insignificant for all (9) main canal flows downstream. The same applied to 7 out of 9 tertiaries of Goa 1. On the other hand, Goa 2 results indicated significant differences ( $p < 0.05$ ) for all (9) tertiaries and 8 out of 9 main canal flows downstream of the devices. Average rice yields for areas commanded by each tertiary along Goa 1 for the January/April, 1996 season was  $4.0 \text{ t ha}^{-1}$ , whereas that of Goa 2 was  $2.85 \text{ t ha}^{-1}$ . There was better irrigation water supply for Goa 1 than for Goa 2. For Goa 1, the mean hydraulic sensitivity for the tertiaries ( $p < 0.025$ ) was the same as that of the main canal downstream the weir devices. Mean hydraulic flexibility for both canals was equal to unity and, thus, sufficing the primary condition for a device to be proportional. For Goa 2, the tertiary mean hydraulic sensitivity was 0.035, whereas that of the main canal downstream the turnout point was 0.015. Their respective

values of hydraulic flexibility were 1.9 and 1.6. Thus, water was not proportionally distributed along Goa 2.

**Key words:** Canal flow, hydraulic flexibility, sensitivity, irrigation

### **Growth and yield performance of maize grown under supplementary irrigation from gully flow in Tanzania**

Bakari, A.M.

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A study was conducted to assess the growth and yield performance of maize grown under supplementary irrigation using gully flow from large external catchment. Two fields measuring 180 m x 60 m size were used. One of the fields (F1) was dominated by fine sandy loam soils, and the other field (F2) was dominated by silty clay loam soils. Three water application treatments were applied to each field, with treatments: flat cultivation without water conservation or supplementary irrigation (FC), flat cultivation with water conservation but without supplementary irrigation (WC) and flat cultivation with water conservation and supplementary irrigation from gully flow (WCIR). Supplementary irrigation when applied to plots with water conservation improved the depth effective rainfall. However, when direct rainfall amount exceeded 40 mm, supplementary irrigation from gully flows resulted into wastage of water through runoff and deep percolation. The effect of prolonged dry spells on soil moisture status was reduced by supplementary irrigation, especially in soils having higher water holding capacity. Grain yields were 1.9 and 2.5 t ha<sup>-1</sup> from FC, WC and WCIR treatments, respectively in F1; and 1.8 and 2.7 t ha<sup>-1</sup> from treatments FC, WC and WCIR respectively in F2. Biomass yields were 6.7, 6.0 and 5.6 t and 5.6 t ha<sup>-1</sup> from treatment WCIR, WC and FC, respectively in F1; and 7.4 and 4.2 t ha<sup>-1</sup> from treatments WCIR, WC and FC respectively in F2. In F1, both biomass and grain yields from all treatments were not significantly different while for field F2 both biomass and grain yields from treatments WCIR were significantly higher than those from treatment FC (p<0.05).

**Key words:** Effective rainfall, soil moisture, water conservation

### **Effect of tillage on soil moisture conservation in a semi-arid environment in Tanzania**

Nyanoka, W.

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Soil management systems affect soil physical properties and, thus can influence crop performance. This study investigated the effect of tillage-induced conditions on soil moisture conservation in a semi-arid environment using selected parameters under a maize crop (*Zea mays* L.) at the Sokoine University of Agriculture (SUA) farm on a kaolinitic sandy clay loam (Oxisol). The tillage treatments were: ploughed (P), open furrow (OF), and ploughed and harrowed (PH). Two cropping treatments were applied i.e. absence of maize crop (bare, B) and presence of maize crop (cropped, C). Bulk density decreased after tillage while soil strength increased. Tillage produced different surface roughness conditions and, thus influenced runoff,

soil moisture content and maize grain yield. The presence of weeds reduced runoff, especially in open furrow (OF) treatment. Tillage created soil surface roughness and soil conditions that favoured the maize crop growth. Soil conditions for ploughed (P), and ploughed and harrowed (PH) treatments favoured maize crop growth. This was indicated by relatively higher maize yield for ploughed (P), and ploughed and harrowed (PH) treatments than that for the open furrow (OF) treatment. The lower maize yield for open furrow (OF) treatment indicated unfavourable conditions for the maize crop growth.

**Key words:** Bulk density, harrow, plough, run off, soil strength

### **The impact of tsetsefly control on the land use of a semi-arid zone of Chiawa in Zambia**

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Subjecting land to use regardless of its resource capability can result in fragile environments being degraded through processes like overgrazing, deforestation and application of inappropriate land use practices. A study to assess the impact of tsetsefly control on the land use of a semi-arid zone was carried out in Chiawa, Kafue District of Zambia. Aerial photographs together with supplementary data from the field survey were used in deriving the land use and land cover classifications of the study area. A land capability classification was carried out in part of the study area to assess the current land utilisation and management. Despite the eradication of the flies in the area, there was no meaningful change in land use over the years. In most of the study area, the land was still under natural vegetation. In some parts of the area, fields had been abandoned for several years. Tsetsefly control, therefore, must be prioritised in areas where a development of the natural potential is feasible.

**Key words:** Cultivation, environmental degradation, land cover, land management

### **Land suitability for producing different crops using the digital land resources database eastern Tanzania**

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A study was conducted in Morogoro, Tanzania to evaluate land suitability for producing different crops using the digital land resources database. Land resources data for climate (rainfall and temperature), physiography and soils and socio-economic were collected and compiled from field surveys and other sources. The results showed that 57% of the area could be used to produce maize, 85% to produce citrus, 22% paddy and 78% to produce sesame; with production potentials ranging from moderate to poor for all studied LUTs. The major limitations were soil erosion, nutrient availability, rooting condition and wetness. Citrus was more suited to the area, followed by sesame, maize and lowland rice. The study has demonstrated that greater capability for storing, displaying spatial and non-spatial

data in different forms and scales, data analysis and computation of land evaluations exist when land resources data are captured in digital format.

**Key words:** Land use planning, production potential, soil erosion

### **Land use change under traditional irrigation activities Tanzania**

Rugenga, E.

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An assessment of land use changes due to traditional irrigation activities was conducted in four villages around Ruaha Mbuyuni in Tanzania. Three sets of aerial photographs (1955, 1976 and 1999) were used, interpreted on a mirror stereoscope and analysed using GIS-ARC/INFO program. The area of each class was calculated for each data set from which the rate of expansion of irrigated farms was determined. A survey using a questionnaire was conducted to collect information on the historical changes in natural resources and socio-economic activities responsible for land use changes. It was clear that irrigated fields expanded by 2056.8 ha and 1528.6 ha with expansion rates of 97.94 ha yr<sup>-1</sup> and 66.46 ha yr<sup>-1</sup> from 1955 to 1976 and 1976 to 1999, respectively. Human population increased from 2,886 to 16,877 people between 1967 and 1998. Irrigation activities increased the extent of socio-economic activities like firewood gathering and building. Total soil nitrogen, available phosphorus and organic matter content were low in all fields. Soil pH values, exchangeable Ca and Mg, and CEC were within the acceptable range for irrigation activities and crop productivity. Soil bulk density was within the acceptable range for water infiltration and plant roots penetration. The soil textural class ranged from sandy loam to sandy clay loam for the topsoil and sandy to clay for the subsoil. It is evident that the patterns of land use changes in the study area were due to irrigation activities in the area which influenced population growth and socio-economic development.

**Key words:** CEC, nitrogen, phosphorus, sodium, water infiltration

### **Accuracy of land cover classification with data generated from landsat thematic mapper satellite data**

Mahuha, F.E.

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This study involved digital image processing and interpretation for land cover classification. Part of Ngerengere watershed in Tanzania covering about 300 km<sup>2</sup> was used for the study. Land cover, which relates to the type of feature present on the surface of the earth of the study area was elaborated. The procedures involved were reconnaissance survey to acquire 'a priori' knowledge about the area, unsupervised classification, supervised classification, field work for ground truthing, image rectification and restoration, and ultimately producing a land cover map of Ngerengere watershed. Overall classification accuracy (OCA) was about 70%, which was below the recommended minimum level of interpretation accuracy value of 85%. The low OCA was substantially attributed by low producer's accuracy for the class of built-up areas which was only 22%. Although the produced land cover map had relatively low OCA, it had a good correlation with the present land use and vegetation. Further analysis using of KHAT

(K) statistics gave a value of 0.65 which is above 0.5 and approaches 1.0, hence acceptance of the land cover map produced from that classification as primary data for land use planning. It also indicated the extent to which the percentages of correct values of an error matrix used were due to true and not by chance agreement. Chi-square distribution to test the goodness of fit of the land cover map elaborated, showed absence of significant difference between the obtained and recommended OCA ( $p < 0.01$ ).

**Key words:** Classification accuracy, digital images, land cover map

### **Land use and impact of cereal-tobacco farming system on Miombo Woodland in Tanzania**

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A study was conducted in the cereal-tobacco farming system in Uyui District (Miombo Woodland), Tabora, Tanzania to assess land use/land cover changes resulting from cereal-tobacco farming systems and to identify socio-economic factors (over 27 years) influencing land use changes in the cereal-tobacco farming system. Uyui district is renowned for flue-cured tobacco as the main cash crop. Broad classes of land use for the years 1970, 1980 and 1997 were established through visual aerial photo interpretation, and digitized into the GIS (ArcInfo/ArcView) software for spatial analysis and map production. The results revealed that there is conversion of the Miombo Woodlands and other forms of vegetation from higher to lower grades. Between 1970 and 1980, a closed woodland of about 1,369 0 ha (30.2%) was changed to cultivated land, 326 ha (7.2%) was changed to bushland, while 722 ha (16%) changed to grassland. Between 1980 and 1997, out of 687.7 ha of closed woodland, only 48.8 ha (7.1%) remain unchanged. About 11,471 ha (81.3%) of the land were under cultivation up to 1997. Agroforestry was a new land use practice in 1997 and occupied 3.9% of the land. Throughout the study period, closed woodland decreased, while cultivated land has continuously increased. The major factors responsible for land use/land cover changes included shifting/rotation cultivation, continuously shortening, fallow periods and demand for fuelwood for curing tobacco. Other factors were farm expansion, growth of population and encroachment on gazetted forests.

**Key words:** Agro-forestry, closed woodland, fallowing, GIS

### **Land use assessment in reserve lands of Mboole-Muyonzo traditional land in Zambia**

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Reliable and up-to-date information about land use practices and available land resources in an area is essential for successful resource development and conservation. A land use assessment study was carried out in Mboole-Muyonzo traditional land, in Southernthern Zambia to assess current land utilisation and management, as well as evaluate a land and demographic change between 1970 and 1991, and, 1969 and 1990 respectively. Sequential

aerial photography was used in assessing land use change. A survey was carried out to assess land utilisation and management and resource degradation in the area. From the study, human population more than doubled in the two decades w, cultivated land expanded by 68.4% between 1970 and 1991, cattle stocking level was 2.4 ha/beast/year (i.e. 40-60% overstocking) and available grazing land was less than half the requirement. Shortage of good arable land forced the inhabitants to cultivate the hilly terrain resulting in all forms of soil erosion. It was also established that land shortage in the area was more as a result of the 1969 coercive displacement of people to give way for the Batoka ranch project. Changes in land tenure structure and distribution in the province are advisable. Periodic surveillance and monitoring land utilisation on both reserve lands and state land farming areas through sequential aerial photography and sequential geographical analysis techniques is necessary for resolving the problems of land degradation in reserve lands and land idleness in state land farming areas. Relocation of some families, especially those who own cattle is advisable.

**Key words:** Land tenure, population growth, soil conservation

### **Land evaluation for rainfed crops in Liti-Tengeru Farm in Tanzania**

Muya, M.N.C.

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A detailed land evaluation using the FAO Framework and Resource Survey for 380 ha was carried out at Tengeru Livestock Training Institute (LITI) in Tanzania to test the adaptability of the 1996 FAO Framework for Land Evaluation for rainfed field crop and pastures; and to establish the land resources inventory of the LITI farm. The concepts and principles in the 1976 FAO Framework were found to work well in the study area. However, some of the methodologies and procedures outlined in the 1984 FAO guidelines had to be refined in order to match with the actual local conditions and crops' performance. Different approaches from those proposed in the 1984 FAO guidelines were used for assessment of moisture availability, temperature regime and soil erosion hazard. Three soil types, namely, mollic andosols, eutric fluvisols and pellic vertisols were identified in the area according to the 1988 FAO-UNESCO legend. The land evaluation results indicated that the major limitations in all soils of the study area were: moisture availability for perennial crops and pastures; nitrogen deficiency; and land degradation through soil erosion and/or soil compaction. The major limitations for using mollic andosols in land mapping unit 34B1 were severe soil erosion, and buried stones which may limit tillage using tractors. This land unit was very fertile and highly suitable for pasture and vegetable and other field crops production if soil erosion is controlled. The eutric fluvisols in mapping land unit 14 C1, were also fertile and suitable for all crops and pastures considered. Supplementary irrigation was necessary for optimum yield of perennial crops and pastures in all land units on the farm. The pellic vertisols in land unit 11C2 was not suitable for most crop production and the pasture grasses. It was, however, suitable for rhodes and buffel grass. The major limitations in using this land unit were: unfavourable soil structure and texture; poor drainage; shallow soil depth; presence of a CaCO<sub>3</sub> toxic layer below 75 cm; high sodium level; and deficiency of the major nutrient elements (N,P,K.). Economic analysis showed that pasture seeds production gave the highest farm net income in the area.

**Key words:** Irrigation, net farm income, pastures, soil moisture

## **Land use practices in a recently opened farmland and their impact on sustainable agriculture in Tanzania**

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A study was conducted in the former Kamenza Forest reserve in Zambia to assess land use practices and their impact on agricultural sustainability. Land resources were characterised in terms of climate, soil type and nutrient status. Two sets of aerial photographs (1991) were interpreted and the results analysed using GIS-ARC/INFO to identify land use pattern before the land was opened for farming. Satellite image (1998) was enhanced in ERDAS image 8.3.1 software for visual interpretation. The result was fed into GIS-ARC/INFO to obtain the land use after the area was opened for farming. A questionnaire survey was conducted to ascertain the socio-economic aspects of the prevailing land use. The study revealed that while climate was suitable for agricultural production, soil pH was low and ranged from 3.7 to 4.9. Total nitrogen, organic matter and calcium were also deficient. Only a small portion of the total land area 8.3% to 8.5% was used for crop agriculture before land was opened up for farming. A large part of it was under closed woodlands representing 84.2-86.5% of the total land area. Upon opening up the area for farming, the area under crop production increased to 23.5 and 25.8% of what was closed woodland showing that there was rapid land clearing. The questionnaire survey revealed that the main farming activity people were engaged in was crop production (98.7%) with maize as the dominant crop (66.6%). It was also shown that there existed a problem of massive tree cutting (51.3%) and low utilisation of agricultural inputs such as lime (1.3%).

**Key words:** Climate, land resources, soil nutrients

## **Performance of rainwater harvesting and storage for supplementary irrigation on paddy rice production in semi-arid Hombolo Tanzania**

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Rainfed lowland rice production covers 75% of the total area (369 000 ha) currently under rice production in Tanzania. It is the most predominant rice ecosystem compared to the irrigated, upland, hydromorphic and inland swamp ecosystems. The main problem with the current rain water harvesting (RWH) systems is that it is subjected to high uncertainties of rainfall amount and distribution. Often water stored in cultivated basins is inadequate to sustain the crop through 20 to 40 day dryspells. This study focused on evaluation of performance of surface water storage for supplementary irrigation of the paddy crop to reduce the effect of long dry spells. There was a significant difference in yield, between with and without supplementary irrigation treatments. RWH with storage and supplemental irrigation produced 3.2 t ha<sup>-1</sup>, while RWH without storage produced 0.2 t ha<sup>-1</sup>. These results show that RWH incorporating a storage reservoir for supplementary irrigation of paddy could help stabilise yields of paddy in semi-arid areas of Tanzania.

**Key words:** upland, hydromorphic, swamp ecosystems

### **Economic feasibility of rain water harvesting for supplementary irrigation in semi-arid Tanzania**

Nyatanyi Mashinga, T.  
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A weather driven simulation model was developed to evaluate the economic feasibility of rain water harvesting (RWH) in the farming system of semi-arid areas of Tanzania. Biophysical parameters were combined with economic parameters to determine the net benefits of RWH system to a farmer. The observed data were obtained from the field trials and historical data, while the predicted data were estimated using the simulation model. The model revealed that the returns accrued to the resources invested could be recovered, particularly in years proceeding the initial year of investment. This was because the storage tank was a long term asset which generated continuous benefits for several years. This was predicted from the high yields obtained when harvested rain water was applied to crops compared production without RWH storage. Whereas the yields produced under catchment area ratio (CA:CF) of 4:1 and 2:1 with RWH storage were 3.92 and 2.53 t ha<sup>-1</sup> respectively, the yields produced under catchment area ratio (CA:CF) of 4:1 and 2:1 without RWH storage were 1.92 and 2.4 t h<sup>-1</sup>a respectively. Basing on the findings of one growing season data, it was shown that RWH system could be a break through for mitigating the long term effect of erratic and unreliable rainfall in semi-arid areas of Tanzania.

**Key words:** Evapotranspiration, regression, run-off, soil water

### **Landsat thematic mapper and ancillary data for assessment of potential areas for rain water harvesting in Tanzania**

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Rain Water Harvesting (RWH) is a system which can store and redistribute moisture needed to enhance crop yields, in areas where rainfall distribution limit dryland crop production. In regions where rainfall is insufficient to produce crops, water harvesting offers an opportunity to bring such areas under cultivation. This study used a nested procedure, combining coverage of a small sample area by Landsat Thematic Mapper (TM) Satellite imagery, conventional photo interpretation and analysis of soil and topographic maps to identify potential areas for RWH cropping system. Computer pattern recognition techniques were used to discriminate soil information from the Landsat Thematic Mapper (TM) satellite data on a sample area. Soil mapping units from a conventional soil survey and aerial photo interpretation were matched to the classified soil spectral map for interpretation and description of the generated classes. Field investigations were done to confirm the results of the sample area which was then extended to a larger area by extrapolation using computer algorithms. Results showed that combination of Landsat TM data and ancillary data could replace extensive field surveys in identifying suitable area for TWH especially where ground truth is available and the landscape is sparsely vegetated.

**Key words:** Moisture, photo interpretation, satellite imagery, spectral map

## **Performance of physically based models in designing rain water harvesting in cropping systems in Tanzania**

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Three physically based models were used to simulate the effects of rain water harvesting on Sorghum yield in semi-arid Hombolo, Dodoma, Tanzania over three seasons. The models were: Runoff estimation model (THIRST), crop growth model (PARCH), soil water availability Mode. Different components of the models relevant to rain water harvesting were combined to form a complete model to estimate runoff, soil moisture content and crop yield. Rain water harvesting with storage was simulated by supplying runoff collected and stored in reservoirs as supplementary irrigation water for days when soil moisture content was below the allowable value. The performance of the models was tested by comparison between estimated and measured values using regression analysis. There was a fairly good agreement between observed and simulated runoff for a 10 x 20 m catchment ( $r^2 = 0.804$ ). For a 10 m x 40 m catchment the correlation between measured and estimated runoff was relatively low ( $r^2 = 0.712$ ). The simulated moisture trend equalled the measured soil moisture ( $r^2 = 0.607$ ). However the model tends to overpredict soil moisture content. The trend of simulated sorghum exhibited a direct relationship of yield increase and water quantity and distribution with correlation coefficient ( $r^2 = 0.622$ ). The model was, however, inadequate in predicting the upper limit of water input and hence the effects of water logging on crop yield. From the study a number of recommendations were made: (i) the runoff sub-model should incorporate a subroutine for simulating surface depression storage resulting from the changing surface micro relief, (ii) rain intensity files should be provided where possible for more reliable results, and further work should be done on the simplified rainfall disaggregator to develop more reliable results, (iii) validation of Raws and Brakensiek (1989) pedotransfer functions for soils of semi-arid areas is required, (iv) the soil water balance sub-model of PARCH should be modified to simulate the lateral soil water flows, infiltration and drainage with greater perfection, and (v) the PARCH model should develop the ability to simulate the effects of anaerobes in the root zone with greater perfection by either reducing establishment during early growth, or by reducing root uptake of water during later growth stages.

**Key words:** PARCH model, runoff, sorghum, THIRST

## **Crop performance under rain water harvesting in semi-arid central Tanzania**

Mbanguka, P.G.L.

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Crop production in semi-arid parts of Tanzania is limited by rain failure or short duration. This problem could be minimised by harvesting rain water during the rainy seasons and using it for crop production when rains recede. A study was conducted to quantify maize and sorghum performance due to rain water harvesting as a supplement to rainfall in arid and semi-arid central Tanzania. In the experiment, a cropped field of 5 m x 10 m was located downstream of uncultivated catchment area which served as treatments. These included: catchment area of 5 m x 40 m (4:1 treatment), catchment area of 5 m x 20 m (2:1 treatment) and no catchment (0:1

treatment or control). During rain storms, water was harvested from the catchments and added to the cropped field. The runoff water was either applied directly (without storage) or was stored in a small reservoir dug between the catchment area and the cropped field (with storage). Crop grown under the 4:1 treatment with storage yielded the highest in both maize (3.26 t ha<sup>-1</sup>) and sorghum (3.22 t ha<sup>-1</sup>), followed by that under the 2:1 treatment with storage (2.18 t ha<sup>-1</sup>) for maize and (2.67 t ha<sup>-1</sup>) for sorghum. Therefore, rain water harvesting with storage produced higher maize and sorghum yield as compared to the same treatment without storage. However there was no significant difference in yield among treatments under direct application of the harvested water and that of no rain water harvesting, although crops grown under treatment of 2:1 produced relatively higher yield (2.14 t ha<sup>-1</sup>) for maize and lowest (1.48 t ha<sup>-1</sup>) for sorghum followed by that of area ratio of 4:1 (1.77 t ha<sup>-1</sup>) for sorghum, whereas that of treatment of 0:1 yielded the lowest (1.69 t ha<sup>-1</sup>) for maize and ranked the third (1.80 t ha<sup>-1</sup>) for sorghum.

**Key words:** Down stream, Maize, rainwater, sorghum

### **Adoption of pandey bioeconomic model for evaluating the economic feasibility of rain water harvesting (RWH) in semi-arid areas of Tanzania**

Nyatanyi Mashinga, T.  
Sokoine University of Agriculture, Tanzania

A weather driven simulation mode was developed to evaluate the economic feasibility of rain water harvesting (RWH) in the farming systems. The biophysical parameters were incorporated with the economic parameters to determine the net benefits of RWH system to a farmer. The model is composed of the biophysical component which consists of the following submodels, rainfall-runoff, soil water balance, evapotranspiration, and the economic submodel which consists of the input-output prices relationship component. The model was calibrated using historical climatic data obtained from meteorological stations at experimental site. The observed data were obtained from the field trials and historical data, while the predicted data were estimated using the simulation model. A 1:1 graph was produced in which a straight line passing through the origin was fitted to the data. The model revealed that the returns accrued to the resources invested could be recovered, particularly in years proceeding the initial year of investment. This is because the storage tank is a long term asset which generates a stream of benefits for several years. This can be reflected by the high harvests under RWH storage, compared with the yield without RWH storage. Whereas the yields produced under catchment area ratio (CA:CF) of 4:1 and 2:1 with RWH storage were 3.96 and 2.53 t ha<sup>-1</sup> respectively, the yields produced under catchment area ration (CA:CF) of 4:1 and 2:1 without RWH storage were 1.92 and 2.4 t ha<sup>-1</sup> respectively.

**Key words:** Catchment area ratio, rainfall-runoff, storage tank

## **Effect of the Hombolo reservoir water quality and soil properties on crop performance**

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A study was conducted at Hombolo Irrigation Project in Dodoma, Tanzania to assess the water quality of Hombolo reservoir and the effect of soil properties on crop performance. The electrical conductivity of the reservoir water (EC<sub>w</sub>) varied between 0.375 mS cm<sup>-1</sup> when rainfall was highest and 6.3 mS cm<sup>-1</sup> when precipitation was lowest. The soils were neither saline nor sodic. Soil electrical conductivity (EC<sub>e</sub>) ranged from 0.05 mS cm<sup>-1</sup> in the Cambisols to 0.30 mS cm<sup>-1</sup> in the Vertisols. Soil pH ranged from 5.3 (slightly acidic) in the Cambisols to 7.5 (mildly alkaline) in the Vertisols. Soil saturated hydraulic conductivity (K<sub>s</sub>) differed significantly between Vertisols (11.0 cm d<sup>-1</sup>) and Cambisols (77 cm d<sup>-1</sup>). Reference evapotranspiration was high during the dry, hot and windy months when it reached 9.1 mm day<sup>-1</sup>. Irrigation application efficiencies ranged from low to high, 45 to 65%, respectively in sloping fields dominated by Cambisols and very high (80%) in flat fields dominated by Vertisols. TMaize crop had yield of 2.5 t ha<sup>-1</sup> in Cambisols, while in Vertisols the yield was barely 1.6 t ha<sup>-1</sup>. It was concluded that the Hombolo reservoir water is saline, hence, water should only be used for irrigation when its electrical conductivity is below 2 mS cm<sup>-1</sup>.

**Key words:** Conductivity, drainage, evapotranspiration, irrigation, salinity

## **Effect of Mswiswi watershed degradation on stream flow in Usangu village irrigation project in Tanzania**

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Mswiswi watershed is one of the 5 watersheds used by Usangu Irrigation project as source of water. The effect of its degradation on stream flow was investigated by establishing four watershed degradation scenarios. The established degradation scenarios were 1960-65, 1965-75, 1975-86 and 1986-92. The 1960-65 degradation scenario was used as the control period i.e. the period for which watershed degradation was at the minimum level. Aerial photographs analysis for 1977 and 1992 showed that: watershed forest loss was 0.105, 0.032 and 0.497 km<sup>-1</sup> year<sup>-1</sup> for mixed forest, forest reserve and low dense miombo woodland, respectively. Soil degradation through gully expansion was 0.049 km<sup>2</sup> year<sup>-1</sup>. There was a general decrease in watershed storage and watershed loss factor from the degradation scenario of lower order (1960-65) to that of the higher order scenario (1986-92). Watershed degradation parameters such as curve number and watershed degradation factor were on the contrary increasing. Stream flow from Mswiswi watershed was affected by both climatic changes and watershed degradation. The developed runoff and base flow models were run for equal rainfall events to evaluate the effect of watershed degradation alone. Results from the model show that runoff increased as the watershed was degraded for equal rainfall events. In the case of base flow, model utilisation outputs showed that watershed degradation caused cyclic trends of base flow variability. The maximum and minimum base flows for equal rainfall had recurrence intervals

of ten years. The magnitude of maximum and minimum base flows decreased with time as watershed was degraded for equal rainfall events.

**Key words:** Base flow, curve number, forest, runoff

### **Pedotransfer functions parameters for Itogolo soils of Sukumaland catena in Tanzania**

Orari, R.B.M.

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Pedotransfer functions (extensions) are semi-empirical models which relate soil hydraulic properties with easily measurable soil properties such as bulk density, texture, moisture content and soil water pressure. The value of these parameters differs spatially depending on soil properties and the model selected. The purpose of this study establish Van Genuchten model parameters for Itogolo (Dystric Eutric Regosol) soils of Sukumaland catena. . To validate the model, the predicted hydraulic properties, ie. moisture retention characteristics [ $\theta(h)$ ] and unsaturated hydraulic conductivity [ $K(h)$ ] were compared with the measured hydraulic properties. Moisture retention characteristic was determined by relating volumetric moisture content ( $\theta$ ) measured by Neutron probe to soil water pressure ( $h$ ) measured by tensiometer connected to mercury manometer. Falling head method was used to measure saturated hydraulic conductivity and instantaneous profile method was used to measure unsaturated hydraulic conductivity. The value of  $n$  ( $= 2$ ) was found to be constant for different depths for both treatments. The value of  $a$  was found to vary with depth and is given by linear relationship  $a = aZ + b$ , where  $a$  and  $b$  are constants,  $Z$  is depth. A good correlation of the predicted and measured hydraulic properties was observed. The correlation coefficient, for both treatments, varied from 0.89 to 0.98, for moisture retention characteristics, and 0.83 for hydraulic conductivity. It is clear, therefore that Van Genuchten model could be adopted for prediction of  $\theta(h)$  and  $K(h)$  for Itogolo soils, where  $n = 2$  and  $a = aZ + b$ .

**Key words:** Catena, conductivity, soil water pressure, Van Genuchten, water content

### **Pedo-transfer functions for estimation of hydraulic properties in Morogoro soils, Tanzania**

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A study was conducted to evaluate some selected pedotransfer function (PTFs) for soil water retention (SWR) and saturated hydraulic conductivity ( $K_s$ ) using soils from Sokoine University of Agriculture farm. The  $K_s$  values were determined using the double ring and tension infiltrometer methods. Representative soil physical properties (RSPPs) for each soil profile studied were calculated using the ratios of individual soil profile horizons depths divided by the total depth of the soil profile. Good estimates of SWR were obtained by Tomasella and Hodnett (1998) PTFs. Estimates of  $K_s$  proved unreliable by the evaluated PTFs. Simple linear multiple regression models were developed for SWR and  $K_s$  using soil physical properties. Soil texture, BD and OC contributed significantly ( $p < 0.05$ ) to the developed regression equations

for SWR characteristics at different matric potential. Retained soil water contents significantly ( $p < 0.05$ ) correlated with percentage clay. Only representative percentage clay had a significant ( $p < 0.05$ ) contribution to the developed regression equation for  $K_s$  estimation. Generally, the  $K_s$  values estimated matched with measured values well with mean differences not significantly different from zero. The developed PTFs for soil WRC and  $K_s$  gave good estimates compared to evaluated PTFs.

**Key words:** Soil texture, Tomasella and Hodnett, water

### **Evaluation of Water Budget technique for determination of effective length of growing seasons under different climatic conditions in Malawi**

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A study was conducted in Malawi, to evaluate the water budget technique for the determination of the effective length of the growing season under different soil and climatic conditions. Two criteria were used to achieve the objective, namely, rainfall and water budget (climatic data, soil and plant characteristics). Historical rainfall data were tested for homogeneity and statistical distribution using RAINBOW computer programme. All the stations, except Dedza, were homogeneous ( $p < 0.05$ ). The coefficient of determination ( $R^2$ ) suggested that the onset and end of the growing season could be approximated by normal distribution, while annual rainfall could be approximated by lognormal distribution. Three years of historical rainfall data were used to calibrate IRSIS as a predictor of daily runoff. The calibration of the rainfall criterion using the water budget criterion indicated that the onset of the growing season could be defined as, a day when a running total of 30 mm of rain is accumulated in a decade with no dry spell of  $>10$  days occurring in the following 30 days. The results of the start and end of the growing season indicate that the rainfall criterion used in this study can be adapted for Chitedze and Makoka. The water budget criterion predicted onset dates closer to when farmers usually plant maize than the rainfall criterion. Both criteria revealed that Mangochi, Ngabu, Makhanga and Chileka have short growing seasons and high occurrence of dry spells within the growing season. Water conservation measures and/or supplemental irrigation should be advocated for in these areas for sustainable crop production. Using runoff plot, the study also showed that the Curve Number (CN) value in plain plots was higher than in contour plot. It is recommended that the rainfall criterion which does not require a lot of input data should be calibrated using a more accurate approach (water budget) to establish appropriate threshold and conditions for different stations.

**Key words:** Curve number, dry spell, IRSIS, runoff

### **Evaluation of rainfall intercreption models in Lusaka, Zambia**

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Rainfall interception is a component of effective rainfall and is an important component in agriculture because of the latter's use in irrigation and drainage projects. A rainfall interception

study was carried out at Kabanana farm a peri urban area in Lusaka, Zambia to evaluate and validate the models developed to represent rainfall interception loss. Results showed that the interception process by a maize plant brought about an interception loss of 10%. Interception loss without stemflow was 27.4%, implying that 17.4% of incident rainfall reached the ground by flowing down the stalk of the maize plant as stemflow. Of the four models tested the models developed by Merriam (1960), Leonard (1965) and De Jong and Cameron (1979) did not represent the process of interception by a maize plant. The linear regression model adopted by Gash (1979), which is insensitive to canopy structure, was 93% significant.

**Key words:** Evapotranspiration, irrigation, stem-flow

### **Evaluation of soil conservation practices in Mbinga District, Tanzania**

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Soil erosion is widespread on the sloping lands of southernthern Higherlands of Tanzania, partly due to frequent and intense rains. Indigenous soil conservation practices, such as, Ngolo and ridges have for different reasons failed to completely eradicate soil erosion problems. This study was conducted in the Matengo Highlands of Mbinga District, Tanzania to evaluate soil conservation practices in Tukuzi Village. The study practices consisted of bare plot (BP), ridge farming (RF) and Ngolo-Matengo pit system (NF). Similar treatments at site B were designated as BPB, RFB and NFB, respectively. Treatments NF were planted with maize. Simple correlation and linear regression equations relating total rainfall, kinetic energy and erosivity index EI30 to soil loss were high in BP followed by RF and least in NF. BPB showed low correlation between EI30 and soil loss at site B. There was greater soil loss in bare than in ridge and ngolo treatments. Maize yield was not significantly different ( $p>0.05$ ) between treatments. NF was in most cases found effective in soil properties conservation followed by RF and BP treatment.

**Key words:** Moisture conservation, Ngolo, ridging, soil erosion

### **Land resources degradation in Bumwi-Sudi rice irrigation project, Zanzibar**

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Assessment of land resources degradation was conducted in Bumbwi-sudi small-holders rice irrigation scheme, Zanzibar to determine the impact of rice irrigation expansion on land use and demography.. Two sets of aerial photographs (one in 1977 and another in 1989) were used, interpreted and analysed using GID-ARC/INFO and ARC/VIEW programmes. Stratified random sampling was conducted for soil physical and chemical analyses.. Both irrigation and drainage water quality assessment was conducted. The results showed that paddy rice plantation expanded by 339.5 ha between 1977 and 1989; human population increased by 10 542 (at annual growth rate of 6.5%) during the same period. Vegetation was reduced by 29-1% due to paddy rice production. Firewood gathering (93%), crop cultivation (92%), and livestock grazing (20%) were the major socio-economic activities contributing to land resources degradation in

the study area. Total soil nitrogen (0.07-0.28%) available phosphorus for all fields (mean 0.45 ppm), and exchangeable Ca (2.43-3.51 cmol kg<sup>-1</sup> were very low in all soils). Therefore, total N, available P, OM content and exchangeable Ca were limiting for paddy rice producing. Both irrigation and drainage water had EC=1.90 dS m<sup>-1</sup> for irrigation and 2.00-2.50 dS m<sup>-1</sup> for drainage water.

**Key words:** ARC/VIEW, GID-ARC/INFO, nitrogen, phosphorus, electrical conductivity

### **Effect of shifts in rainfall pattern on rainfall characteristics in Tanzania**

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This study was conducted to establishing the existence of significant shifts or departures in rainfall pattern and the effect this may have on the start dates of the growing season from the work was done in six agro-ecological zones in Tanzania. The onset of the growing season for the various agro-ecological zones was determined using a calibrated rainfall-based criterion. This was achieved through use of a water balance simulation model. Results show that all stations in the six agro-ecological zones experience shifts in the rainfall pattern. Significant negative correlations between start dates and length of the growing season existed in all the stations. Coastal Forest and thicket (zone II), Acacia-Commiphora Thornbush (zone V) and Branchystegia-jubernadia Savanna (zone VI) was found to correlate negatively with start dates of the growing season. However, start dates of the growing seasons for stations in the Moist Forest Mosaic (zone I), Montane Forest (zone III) and Acacia-Savanna and grasslands zones (zone IV) appeared to have no relationship with seasonal rainfall. Stations in all the agro-ecological zones were more prone to dry spells when the growing season started early or late. A high proportion of dry spells was observed in zones I and V when rainfall commenced early. A higher risk of dryness was also noted for short rains during late start of the growing season. No association existed between the departures in start dates of growing season and the occurrence of ENSO and La-Nina events.

**Key words:** Agroecological zones, coastal forest, thornbush

### **Landcover dynamics and hydrological functioning of wetlands in Uusangu plains in Tanzania**

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In the Usangu Plains of the Upper Great Ruaha River Catchment in Tanzania, the hydrology of the wetlands and the downstream flow regime changes in response to changes in land use and cover was investigated through analysis of remotely sensed images and modeling. A hydrological model for the eastern wetland that accounts for the water balance was developed. This model was used to evaluate the hydrology of the eastern wetland in response to changes in land use and cover and the amount of inflows into the eastern wetland required to maintain a specified outflow downstream of the wetland. easterneasternA small wetland locally called *Ifushiro* located in the upstream of the eastern wetland was also investigated to evaluate its

contribution to dry season flows. The analysis involved a detailed hydrometric monitoring and modeling using Visual MODFLOW software. The *Ifushiro* wetland was modulated by the changes in land use and cover on the upstream. Since 1958, increasing diversion of water has caused average dry season inflows to the eastern wetland to decrease from approximately 15.0 to 4.3 m<sup>3</sup>s<sup>-1</sup>. This led to a reduction in the average minimum dry season surface area of the wetland from approximately 160 to 93 km<sup>2</sup>. Since the early the 1990s, the decrease in dry season water-levels within the wetland resulted in prolonged periods of zero flow in the Great Ruaha River, with severe consequences for the ecology of the Ruaha National Park. The wetland model enabled calculation of the inflows required to maintain specified discharges. To maintain a flow of 0.5 m<sup>3</sup>s<sup>-1</sup>, as the minimum required flow for maintenance of fish habitat and the current ecology of the Park, required an average dry season inflow of approximately 7.0 m<sup>3</sup>s<sup>-1</sup> into the eastern wetland in the dry season. The results from this research demonstrate the value of combining different research methods/approaches and the use of simple models to examine system functioning to assist decision-making.

**Key words:** downstream, fish habitat, Visual MODFLOW, visual mode flow

### **Determination of the onset and length of growing seasons in Tanzania**

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This study was based on 15 weather stations in Tanzania to determine the start, the end and the length of effective growing season. Weather data 30 to 37 years were collected and two criteria were used to define the events of interest; namely rainfall, and rainfall plus evapotranspiration. There was significant ( $p < 0.05$ ) variability in the start and end dates in almost all stations. There was no clear trend in the start and end dates of the effective growing season in time and space. Furthermore, the rainfall plus evapotranspiration criterion was insufficient to define the end of the growing season. Knowledge of soil-water storage was required to define this event more realistically. Stations which appeared to have longer growing seasons like Shinyanga, Mpwapwa, Maswa and Lindi; had very poor rainfall distribution and high probabilities of dry spells within the growing season. Supplementary irrigation, water conservation or water harvesting practices were, thus, the possible solutions for sustainable crop production these areas.

**Keywords:** Evapotranspiration, rainfall, soil water, weather

### **Spatial impact of land use on land resources in Siavonga District, Zambia**

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The construction of the Kariba Dam necessitated translocation of 57,000 Tonga people of the Zambezi basin to within the surrounding areas on both sides of Zambia and Zimbabwe. This study assessed the implication of the resettlement of up to 6,000 Tonga speaking people into Lusitu area, Siavonga District of Zambia. Aerial photo interpretation for the year 1970 together with Landsat TM images for the years 1986 and 1995 were used. It was clear that two different

processes contributed to land resources degradation, namely, (a) conversion of most of the available forests at all categories and other forms of vegetation from higher grades to lower grades; and (b) lack of comprehensive reforestation programmes. It also revealed that the annual deforestation rate in Lusitu area from 1970 to 1995 was 483.28 ha y<sup>-1</sup> (2.0% y<sup>-1</sup>). Between 1970 and 1986, it was 366.4 ha y<sup>-1</sup> (1.55% y<sup>-1</sup>), while for 1986 and 1995 the deforestation rate was 691.0 ha y<sup>-1</sup>. There was an increasing rate of deforestation in Lusitu from 1986 to 1995 compared with 1970 to 1986. In Siavonga district, between 1986 and 1985, the rate of deforestation was 3772.8 ha y<sup>-1</sup> (2.2% y<sup>-1</sup>). The deforestation rate for Lusitu area for the period 1986 and 1995 was higher than for whole Siavonga District, while for the period 1970 to 1986, it was lower than that for Siavonga District. A general trend of increase in cultivated areas was noted along with a trend in the evolution of bad land was identified. A spatial pattern of deforestation appeared to be related to the settlement distribution pattern. The increase in both human and livestock population explained part of the rate of deforestation in particular as well as land degradation in general. A general trend in cultivation of hilly areas and close to river banks was noted. Desertification conditions were also observed at the confluence of Zambezi and Lusitu

**Keywords:** Deforestation, resource degradation, Tonga

### **Determination of humidity-referenced potential areas for crop production in Tanzania**

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This study was conducted to determine the potential areas for production of maize, sorghum, groundnuts and beans based on humidity levels in Zambia. Rainfall and evapotranspiration data for 97 stations were collected from the Directorate of Meteorology, while the maximum water holding capacity, the growing periods and the crop coefficients of the selected crops were estimated from those available in the literature. Data analysis was based on the hydrologic budget balancing model for stations. Potential areas were delimited by grouping of stations of the same humidity levels. It was found that the approach provided basic information on potentials and could, therefore, be used for agricultural planning purposes. A fairly large percentage of areas established through this method, especially for maize and sorghum, coincided with the current production areas. Among the three crops, beans showed the greatest potential over the country's total area and only 20% of it was utilised while groundnuts had the highest percentage of its potential area unutilised.

**Key words:** Evapotranspiration, groundnut, hydrologic budget

### **Land use patterns in Morogoro and Kikundi river catchments in Tanzania**

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Land in the Morogoro and Kikundi River Catchments of Tanzania's Uluguru Mountains use was evaluated. The catchment occupies an area of 2300 ha at elevations of 550 - 2 000 metres above sea level. Mean annual rainfall is estimated to range from 800 mm to over 1500 mm while

mean annual temperature range from 25 to 19°C. Farmlands (68% of the catchments) proved the main land use, extending to steep (over 30% slopes and associated with sheet erosion against which little effort was made to control. Four major land use units could usefully be recognised; namely, water source areas, woodland, upper catchment and lower catchment. The first two served important protective functions, the water-source areas, occurring locally throughout the areas, should be inviolate. The woodland areas, in the lower part of the catchment, were viewed as potential fuel source – under appropriate management. Agricultural activity should be restricted to the upper (wet) and lower (dry) catchments and be planned taking into account slope categories. There was concern among farmers about low production levels for their crops and there was no evidence of contact with effective agriculture and forestry extension programmes. It was concluded that cultivation should be restricted to gentle (0-15%) slopes (especially maize) and moderate (15 - 30%) slopes (especially bananas). Where use of the steeper slopes is unavoidable, growing of coffee would be preferred. In all cases, more attention needs to be put to the active application of soil conservation measures.

**Key words:** Banana, erosion, maize, sheet, woodlands

### **Effect of forest types on water input in Mindu Forest Reserve Tanzania**

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Effect of selected sites of miombo woodland and dry semi-evergreen forest in Tanzania, on water input, was evaluated based on hydrologic processes. Significantly greater net rainfall was observed in the woodland (95.3% of gross rainfall G.R.) than in the forest (78.9% of G.R.). Overall, the woodland yielded significantly more water (net rainfall) per given incident rainfall than the forest. Loss of part of the incident rainfall through interception was 21 and 5% of G.R. for the forest and the woodland, respectively. Such a difference makes the woodland of greater benefit for water intake in catchment areas than the forest. However, loss of water through surface rainfall was significantly greater in the woodland (2.7% of G.R.) than in the forest (1.1% of G.R.). Inversely, the forest showed consistently higher soil moisture levels than the woodland, thereby indicating a possibly greater capability of conserving water over a long period of time. Nevertheless, this can only be implied as the differences were not significant and as field capacity and wilting point of the soils were not determined. The miombo woodland and the dry semi-evergreen forest to had significantly higher relative humidity and less evaporation.

**Key words:** Forest, Miombo woodlands, rainfall, soil moisture

### **Optimisation of nitrogen mineralisation from decomposing *Gliricidia sepium* leaves for maize growth and yield**

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Decomposition (mass loss) and mineralisation studies were conducted at Kitete village, Kilosa district, Tanzania to control the rates of decomposition and N release from *Gliricidia sepium* (Jaq) Walp leaves through widening their C/N ratios. Litter bags containing *G. sepium* leaves

(150 g bag<sup>-1</sup>) and variable amounts of sawdust (0, 25, 50, 75 and 100% of fixed *G. sepium* were used in the decomposition experiment. Different *G. sepium* leaf rates (1.5, 1.15, 0.76 and 0.38 kg dry leaves plots of 60,45.30 and 15 kg N ha<sup>-1</sup>, respectively and various *G. sepium* and sawdust mixtures containing a fixed amount of leaves (1.5 kg plot<sup>-1</sup>) and variable amounts of sawdust were used in the mineralisation experiments. mineralisation *Gliricidia sepium* alone had significantly ( $p < 0.002$ ) higher mass loss percentage and nitrogen release but decreased with increasing C/N ratio in *G. sepium* sawdust mixtures. Rates of mass loss were influenced by placement depth. Most of the N from *G. sepium* alone was released within 6 weeks. In the mineralisation experiments, nitrate N dominated the mineral N, ranging from 67 to 80%. Nitrogen uptake by maize plants, maize height increment and maize crop yields were significantly greater in plots with correspondingly the highest C/N ratios with positive correlation between nitrogen uptake and maize growth ( $r = 0.76$ ) and maize yield ( $r = 0.858$ ). A 3 – 8 weeks period was critical for high nutrient demand by maize crop.

**Key words:** C/N ration, maize, nitrogen release, sawdust

### **Nitrogen mineralisation and maize yield from a fallow of *Prosopis chilensis* at Morogoro in Tanzania**

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This study was conducted to assess the effect of three-year old fallow of *Prosopis chilensis* (Molina stuntz) on general soil properties, nitrogen mineralisation and maize yeild in an on-going agroforestry experiment at Gairo, Morogoro, Tanzania. Three treatments; trees alone (T), maize (M) alone and trees plus maize (T + M) were considered. The trees alone treatment had higher level of K<sup>+</sup> (1.0 cmol. kg<sup>-1</sup> than other treatments which had the lowest level (0.7 cmol. kg<sup>-1</sup>). Magnesium differed significantly among treatments, with the maize alone treatment having the highest level (2.0 cmol. kg<sup>-1</sup>) while the treatment with trees alone had the least (1.6 cmol. kg<sup>-1</sup>). Total P differed significantly ( $p < 0.05$ ) among treatments with the trees alone treatment having the highest total P (229.6 µg g<sup>-1</sup>), and treatment with maize alone having lowest value (159 µg g<sup>-1</sup>). Sodium and Ca<sup>2+</sup> were not significatly affected by treatments. Total N and available P decreased significantly ( $p < 0.05$ ) with soil depth. In contrast, Mg<sup>2+</sup> and Ca<sup>2+</sup> were higher in the subsoil than in the top soil.

**Key words:** Calcium, magnesium, maize, phosphorus, trees

### **Effect of relay intercropping of *Sesbania sesban* on soil fertility and firewood production at Mafiga in Tanzania**

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This study was carried out at Sokoine University of Agriculture Farm in Morogoro, Tanzania to examine the effect of relay intercropping of *Sesbania sesban* and maize on soil fertility and production of maize and firewood. An existing one year relay intercropping experiment in which *S. sesban* grew after harvesting of maize during the dry season was studied. Firewood

biomass after 1 year of intercropping was 3 t ha<sup>-1</sup>. Maize was planted with and without *S. sesban* at 0, 20, and 40 kg ha<sup>-1</sup> each of nitrogen and phosphorus. Intercropping slightly increased soil mineral N status. Maize grain yield was significantly ( $p < 0.05$ ) higher in *S. sesban* plots without fertiliser (2.43 t ha<sup>-1</sup>) than in the control (2.09 t ha<sup>-1</sup>). The three levels of N and treatment interaction effects had no significant ( $p > 0.05$ ) effect on maize yield. In contrast, the three levels of P influenced significantly ( $p < 0.05$ ) maize grain and stover yields. Maize grain yield from plots of 20 kg P ha<sup>-1</sup> was 2.39 t ha<sup>-1</sup> and 40 kg P ha<sup>-1</sup> was 2.36 t ha<sup>-1</sup> compared with the control (2.02 t ha<sup>-1</sup>). In order to determine decomposition rate and nutrient release of selected species, a 10 week decomposition experiment involving litter bags containing green manure from *Albizia lebeck*, *Gliricidia sepium*, *Senna siamea*, *Sesbania sesban* and *Tephrosia vogelii* was also studied. Significant ( $p < 0.05$ ) differences existed in decomposition in order *Gliricidia sepium* > *Sesbania sesban* > *Albizia lebeck* = *Senna siamea* > *Tephrosia vogelii*; N release in the order ( $p < 0.01$ ) *Sesbania sesban* > *Gliricidia sepium* > *Tephrosia sepium* > *Albizia lebeck* > *Senna siamea* > *Glicidia sepium* > *Sesbania sesban* > and phosphorus release in the order ( $p < 0.01$ ) *Tephrosia vogelii* > *Gliricidia sepium* > *Sesbania sesban* > *Senna siamea* > *Albizia lebeck*. Nitrogen and phosphorus release ranged between 128 -202 kg N ha<sup>-1</sup> and 7.76 - 12.88 kg P ha<sup>-1</sup>. Most of the N and P were released within the first four weeks of decomposition. Based on these results, *Sesbania sesban*, *Gliricidia sepium* and *Tephrosia vogelii* showed greatest potential for use as green manure; and relay intercropping of *Sesbania sesban* and maize has potential in increasing maize yield even without fertilisers.

**Key words:** *Gliricidia sepium*, *Senna siamea*, *Tephrosia vogelii*

## Effect of forest plantations on soil properties at Sao hill forest plantations in Tanzania

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A study was designed to compare selected soil properties under natural *Brachestegia* miombo grassland and vegetation, and adjacent young and old plantations of *Pinus patula* Scheld & Cham and *Eucalyptus saligna* at Sao Hill forest Plantations. Soil samples were collected from paired plots in natural vegetation and adjacent plantations. Soil physical properties (except MC and BD) at 0-5 cm depths did not differ significantly ( $p < 0.05$ ) in plantations compared with their adjoining natural vegetation. Overall, MC was lower in old stands of pine than in the young stands. It decreased under old *E. saligna*. Soil bulk density was higher under pine plantations but decreased under *Eucalyptus* plantations. Soil chemical properties, namely, EC, pH, Total N, P and OC did not differ significantly ( $p > 0.05$ ) for all soil depths under the two plantation species and the adjoining natural vegetation. Organic and available P increased at most soil depths under all stands of both plantation species, but available P increased significantly ( $p < 0.05$ ) at 0-5 cm and 5-10 cm soil depths under old *Eucalyptus*. Nitrate N was significantly ( $p < 0.05$ ) lower at 0-5 cm depth under young pine and at 0-5 cm depth under young *Eucalyptus*, while N was significantly higher under older pine at 0-5 cm soil depths.

**Key words:** *Brachestegia* spp., *Eucalyptus saligna*, Miombo grassland, *Pinus patula*

## Effect of improved fallows of leguminous shrubs soil fertility and maize yield in Morogoro, Tanzania

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A study to evaluate the effect of improved fallows and nitrogen and phosphorus fertilisation on soil fertility was carried out at Gairo, a semi-arid area in Morogoro, Tanzania. Treatments included fallow types (*Cajanus cajan* (l) Millsp, *Gliricidia sepium* (Jac Q) Walp, and included *Sesbania macrantha* Phil and Hultch, *Sesbania sesban* (L); others natural fallow). Other factors included nitrogen and phosphorus fertilisation (0 N and 0 P kg ha<sup>-1</sup>, 20 N and 15 P kg ha<sup>-1</sup>, 40 N and 30 P kg ha<sup>-1</sup> and 80 N and 60 P kg ha<sup>-1</sup>). Wood biomass was significantly ( $p < 0.05$ ) among different shrubs with the highest value 19.20 t ha<sup>-1</sup> for *S. sesban* and least 6.57 t ha<sup>-1</sup> *C. cajan*. Foliar biomass was between 1.63 t ha<sup>-1</sup> (*C. cajan*) and 7.34 t ha<sup>-1</sup> (*G. sepium*). *Gliricidia sepium* fallow enhanced soil fertility better than other fallows. Soil electrical conductivity ranged from 0.07 dSm<sup>-1</sup> for natural fallow to 0.29 dSm<sup>-1</sup> for *G. sepium*; and organic carbon 0.76% (natural fallow) to 2.59% (*G. sepium*). Available P ranged from 2.07 mg kg<sup>-1</sup> (Natural fallow) to 32.46 mg kg<sup>-1</sup> (*G. sepium*), CEC 5.33 cmol kg<sup>-1</sup> (Natural fallow) to 8.87 cmol. kg<sup>-1</sup> (*Gliricidia sepium*). Maize yields and height were highest and *G. sepium* (2.0 m). The natural fallow resulted in maize grain yield of 3.66 t ha<sup>-1</sup>, followed by *S. sesban* 1.9 t ha<sup>-1</sup> and least in the natural fallow (1.56 t ha<sup>-1</sup>). Stover yield was between 3.51 t ha<sup>-1</sup> (*G. sepium*) and 1.2 t ha<sup>-1</sup> (Natural fallow). Also, fallow plots which received N and P fertilisers tended to increase maize leaf unit mat leaf, maize grain and stover N and P concentrations when N and P fertiliser were applied. Maize height increased up 1.8 and 2.2 m for natural fallows and *G. sepium* fallow, respectively. Maize yield was as follows: 4.45 t ha<sup>-1</sup> for *G. sepium* fallow followed by *S. sesban* 3.48 t ha<sup>-1</sup> *C. cajan* 3.30 t ha<sup>-1</sup> *S. macrantha* 3.18 t ha<sup>-1</sup> and least Natural fallow 2.52 t ha<sup>-1</sup>. Stover yield ranged between 4.02 t ha<sup>-1</sup> *G. Sepium* and 2.40 t ha<sup>-1</sup> (natural fallow). The effect of N and P fertiliser, regardless of the effect of fallows, resulted in higher maize height of 2.1 m at rate of 80 N and 60 P kg ha<sup>-1</sup> that at control rate of 0 N and 0 P kg ha<sup>-1</sup> (1.8 m), maize grain and stover had a similar trend, ranging from 2.43 t ha<sup>-1</sup> unfertilised plots, to 4.16 t ha<sup>-1</sup> (full dose plots) and 2.2 t ha<sup>-1</sup> (unfertilised plots) to 3.91 t ha<sup>-1</sup> (full dose, respectively). Improved fallow of nitrogen fixing species at Gairo are promising to reduce problems of soil fertility depletion and height consequently on maize yields.

**Key words:** *Cajanus cajan*, *Gliricidia sepium*, *Sesbania sesban*

## Synchronisation of nutrient release from *Gliricidia sepium* for optimum nutrient uptake by maize at Morogoro in Tanzania

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This study was conducted at Morogoro Tanzania to assess the effect of synchronised mulching of *Gliricidia sepium* on soil nutrient status; nutrient uptake by maize and field performance of maize. Different factors considered and their levels were: mulch application dates, namely, just before sowing (T1) two weeks after sowing (T2), four weeks after sowing (T3), and 6 weeks after sowing (T4). Others included mulch application rates), control (0 kg ha<sup>-1</sup> and 8 kg plot ha<sup>-1</sup> M3) and 10.0 t ha<sup>-1</sup> (1000 kg ha<sup>-1</sup>), 16 kg plot ha<sup>-1</sup> (M4). Nitrogen mineralisation at all

sampling periods showed significant differences ( $p < 0.05$ ) between mulching site except at weeks 1 and 4 for nitrate-N and at 1 and 2 weeks for ammonium-N. Nitrogen mineralisation was not affected by the time of mulching. Nitrate dominated the system throughout the study period. Maize grain and stover yield were not significantly ( $p > 0.05$ ) affected by time of mulch application, but were significantly affected by mulch rates. Mulching time had no significant effect on maize growth and yield; however, it was significant on grain P and stover N uptake.

**Key words:** Ammonium, mulching, nitrate, nutrient uptake

### **Effect of fallow periods of agroforestry legumes on soil fertility improvement and maize and firewood production at Gairo in Morogoro, Tanzania**

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This study was carried out at Gairo in Tanzania to evaluate the effects of fallow periods and types, and N and P fertilisation on soil fertility improvement, maize growth and yield and firewood production. The study factors were fallow period (1, 2, 3 year fallows); fallow type (*Sesbania sesban* (L) merril, *Tephrosia vogelli* (f) hook, *Cajanus cajan* (L) Millsp; and fertiliser (0 kg N and 0 kg P ha<sup>-1</sup>; 0 kg P and 40 kg N ha<sup>-1</sup>; 0 kg N and 40 kg P ha<sup>-1</sup>; 40 kg N and 40 kg P ha<sup>-1</sup>). Tree/shrub species differed significantly ( $p < 0.05$ ) in total biomass production with *C. Cajan* outranking others in 1 year fallow i.e. 10 t ha<sup>-1</sup> and the least value coming from *T. vogelii* (5.44 t ha<sup>-1</sup>). In 2-year fallow, *S. sesban* was outstanding (69.84 t ha<sup>-1</sup>) and the lowest value was achieved with *C. Cajan* (6.79 t ha<sup>-1</sup>); while in 3-year fallow, *S. sesban* was still outstanding (46.02 t ha<sup>-1</sup>) and the lowest value was from *C. cajan* (8.25 t ha<sup>-1</sup>). Shrub wood and foliage N and P concentrations also differed significantly, with fallow period and shrub species. Wood N concentration from 2 year fallow of *S. sesban* was the highest (1.08%) and the lowest value in 2 year fallow was from *T. vogelii* (0.95%). In wood P concentration, 2-year fallow *T. vogelii* outranked the other shrub species. For foliage N concentration, the 2-year fallow of *S. sesban* was outstanding (2.94%), while the least foliage N concentration value was from *C. cajan* (2.52%). In foliage, P concentration from 2-year fallow *T. vogelii* had the least value (0.198%) and the lowest P concentration value in 2 year fallow came from *C. Cajanas* (0.179%). In litter concentration, the values were *T. vogelii* (1.75%), *C. cajan* (1.67%) and *S. sesban* (1.61%) while the values for litter P concentration were *T. vogelii* (2.85%) *S.seban* (1.79%), *C. cajan* (1.36%). Soil electrical conductivity ranged from 0.0 dSm<sup>-1</sup> for a 3 year natural fallow to 0.21 d Sm<sup>-1</sup> for a 3 year *S. sesban* fallow, organic carbon 1.3% for a 3 year natural fallow, 2.41 % for a 3 year *S. sesban*. Maize heights were highest from 1-3 year fallow with *T. vogelii* having (1.23 - 1.25 m) constant cropping (1.14 - 0.88 m). *Tephrosia vogelli* was outstanding in maize yield improvement. The range in yield for 1 - 3 year fallow without fertilization application was *T. vogelii* (4.80 - 6.55 t ha<sup>-1</sup>), *S. sesban* (2.54 - 3.96 t ha<sup>-1</sup>) *C. cajan* (2.09 - 5.43 t ha<sup>-1</sup>), natural fallow (1.80 - 3.03 t ha<sup>-1</sup> and crop 2.66 t ha<sup>-1</sup>).

**Key words:** *Cajanus cajan*, *Sesbania Sesban*, *Tephrosia vogelli*, *Cajanus cajan*

## **Effect of forest management systems on soil conditions of Kitulanghalo Areas in Tanzania**

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A study was carried out at Kitulanghalo Morogoro, Tanzania to investigate the effect of three forest management systems on soil properties. The forest management systems were private, state and public lands. The major group of soils identified were haply-chromic phaezems (typic haplustolls) in the state forest, haplichromic lixisols (typic haplustaffs) in the private forest, Rdod-profondic lixisols (typic phodustalts) and chromi-profondic lixisols (typic haplustafas) in the public land. Each management system was sampled at 4 depths on summits, slopes and valley bottoms for laboratory physical chemical analyses. The public Lands forest management system led to drastic changes in soil properties. It had an altered texture with a significantly high content of sand, and low clay and silt content ( $p < 0.05$ ). The soil bulk density was significantly high ( $p < 0.05$ ) and total porosity and volumetric water content were significantly low ( $p < 0.05$ ). It had significantly lower available water capacity compared to the private forest ( $p < 0.05$ ). The organic carbon, total N, C/N ratio available P, CEC, exchangeable calcium, magnesium, and sodium, total exchangeable bases and % base saturation contents were significantly lower ( $p < 0.05$ ) in the forest management system. The population of soil fauna in the Public land management system also was significantly lower ( $p < 0.05$ ) compared either to the private or state forest management system. The public forest management system had significantly higher ( $p < 0.05$ ) available water capacity, organic carbon and available phosphorus in the 0-15 cm depth and also soil fauna compared to the State forest system. The valley bottoms under private and state forest systems exhibited severe and mild depositions of soil, respectively, from summits and slopes due to erosion.

**Key words:** CEC, founa, nitrogen, organic carbon, silt

## **Farmers' utility of irrigation water supply as a method of assessing irrigation system's performance in Tanzania**

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Models which employ Farmers' Utility of Irrigation Water Supply (FUIWS) in assessing irrigation system's performance were developed. The methodology was tested through a case study at Lower Moshi Farmer Managed Irrigation Scheme (Lower Moshi FMIS). The objective was to investigate FUIWS as a method of assessing the performance of irrigation systems. A non-linear but significant correlation was observed between Relative Water Supply (RWS) and FUIWS with  $R = aenU$ ; where  $R = RWS$  in paddy field,  $U = FULWS$ , with  $a$  and  $n$  being consonants. The scheme model obtained was:  $R = 0.377e1.825U$ . The homogeneity test on the block mean values showed that RWS had the same degree of variability for all levels of FUIWS. This indicated the ability of the scheme model to be used in place of block models. Different "a" and "n" consonant values obtained between blocks indicated different irrigation management levels between blocks. This model was, however, tested in paddy rice only.

**Key words:** Irrigation management, modelling, water use

### **Sprinkler performance evaluation at Mtibwa Sugar Estates in Tanzania**

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A performance evaluation aimed at evaluating Mtibwa sprinkler irrigation system in Tanzania was carried out. The objectives were to evaluate to investigate sprinkler irrigation performance parameters in relation to design recommendations. It was clear that 20% of all sprinkler irrigated blocks had a coefficient of uniformity below 80%. The pressure recorded ranged from 1.8 to 3.2 bar, with 73% of all blocks having sprinklers operating below the designed pressure of 3.2 bar. About 38% of all blocks required longer duration of irrigation than the current practice for the right amount of water to be supplied. The longer required irrigation duration was a result of the application rate caused by low pump operating pressure and consequently low pressure at low pressure at the sprinklers.

**Key words:** Irrigation, pressure, pump

### **Proportioning water-division devices in Njoro ya Goa in Tanzania**

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This study aimed at assessing the performance of proportioning water-division devices in Farmer-Managed Irrigation systems in Tanzania. This was done in Canal I (Goa I), Goa 2 in the existing mud-and-stones water diversion. At Goa 1, the difference between the measured and expected flows was insignificant ( $p < 0.05$ ) for the nine main canal flows downstream of the devices. The same applied to 7 out of 9 tertiaries of Goa 1. Goa 2 results indicated significant differences for all tertiaries and 8 out of 9 main canal flows downstream of the devices. Average rice yields for each tertiary along Goa 1 was  $4.0 \text{ t ha}^{-1}$ , whereas that of Goa 2 was  $2.85 \text{ t ha}^{-1}$ . For Goa 1, mean hydraulic sensitivity for the tertiaries (0.025) was the same as that of the main canal downstream of the weir devices. Mean hydraulic flexibility for both canals was equal to  $= 1.0$ , thus, sufficing the primary condition for a device to be proportional. For Goa 2, the tertiary mean hydraulic sensitivity was 0.035 whereas that of the main canal downstream the turnout point was 0.015, showing differences among the values. Their respective values of hydraulic flexibility were 1.9 and 1.6.

**Key words:** Canal, hydraulic flexibility, irrigation

### **Performance of maize under supplementary irrigation from gully flow in Tanzania**

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A study was conducted to assess the growth and yield performance of maize grown under supplementary irrigation using gully flow from large external catchment. Two fields measuring  $180 \text{ m} \times 60 \text{ m}$  were used; one (F1) dominated by fine sandy loam soils and the other (F2) with

silty clay loam soils. Three water application treatments were applied to each field. The treatments were flat cultivation without water conservation or supplementary irrigation (FC), flat cultivation with water conservation but without supplementary irrigation (WC) and flat cultivation with water conservation and supplementary irrigation from gully flow (WCIR). Supplementary irrigation when applied to plots with water conservation improved the depth effective rainfall. However, when direct rainfall amount exceeded 40 mm, supplementary irrigation from gully flows resulted into wastage of water through runoff and deep percolation. The effect of prolonged dry spells on soil moisture status was reduced by supplementary irrigation, especially in soils having higher water holding capacity. Grain yields were 1.9 and 2.5 t ha<sup>-1</sup> from FC, WC and WCIR treatments, respectively in F1 and 1.8 and 2.7 t ha<sup>-1</sup> from treatments FC, WC and WCIR, respectively in F2. Biomass yields were 6.7, 6.0 t ha<sup>-1</sup>, and 5.6 and 5.6 t ha<sup>-1</sup> from treatment WCIR, WC and FC respectively in F1 and 7.4 and 4.2 t ha<sup>-1</sup> from treatments WCIR, WC and FC respectively in F2. In F1, both biomass and grain yields from all treatments were not significantly different, while for field F2 both biomass and grain yields from treatments WCIR were significantly higher than those from treatment FC at p<0.05).

**Key words:** Effective rainfall, flat cultivation, percolation

### **Effect of tillage on soil moisture conservation in a semi-arid environment in Tanzania**

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Soil management systems affect soil physical properties and thus can influence crop performance. This study investigated the effect of tillage-induced conditions on soil moisture conservation in a semi-arid environment using selected parameters under a maize crop (*Zea mays* L.). The experiment was conducted at the Sokoine University of Agriculture farm in Tanzania, on a kaolinitic sandy clay loam (Oxisol) from. The tillage treatments were ploughed (P), open furrow (OF), and ploughed and harrowed (PH). Two cropping treatments were applied, i.e., absence of maize crop (bare, B) and presence of maize crop (cropped, C). All treatments were replicated three times. Measurements were made for density, soil strength (penetrometer resistance), surface roughness, soil moisture content, runoff and weed density. Bulk density decreased after tillage, while soil strength increased. Tillage produced different surface roughness conditions and thus influenced runoff, soil moisture content and maize grain yield. The presence of weeds reduced runoff especially in open furrow (OF) treatment. Tillage created soil surface roughness and soil conditions that favoured the maize crop growth. Soil conditions for ploughed (P), and ploughed and harrowed (PH) treatments favoured maize crop growth. This was indicated by relatively higher maize yield for ploughed (P), and ploughed and harrowed (PH) treatments than that for the open furrow (OF) treatment. The lower maize yield for open furrow (OF) treatment indicated unfavourable conditions for the maize crop growth.

**Key words:** Bulk density, harrow, plough, run off

**Impact of tsetsefly control on the land use of a semi-arid zone in Zambia**

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Subjecting land to use without regard to its resource capability can result in fragile environments being degraded through processes like overgrazing, deforestation and application of inappropriate land use practices. A study to assess the impact of tsetsefly control on the land use of a semi-arid zone was carried out in Chiawa, Kafue District of Zambia. Aerial photographs together with supplementary data from the field survey were used in deriving the land use and land cover classifications of the study area. Despite the eradication of the flies in the area, there has never been meaningful change in land use over the years. In most of the study area, the land is still under natural vegetation. In some parts of the study area, fields have been abandoned for several years indicating that either the prevailing physical conditions could not allow for continued cultivation of the land or the people migrated for better opportunities. Tsetsefly control, therefore, must be prioritized in areas where a development of the natural potential is feasible. It is a waste of resources to control on tsetseflies control in areas where the reclaimed land can not be utilised productively.

**Key words:** Cultivation, environmental degradation, land cover

**Using the digital land resources database for evaluating land suitability for producing different crop in eEastern Tanzania**

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A study was conducted in Morogoro, Tanzania to evaluate land suitability for different crops using the digital land resources database. Land resources data for climate (rainfall and temperature), physiography and soils, and socio-economic were collected and compiled from field surveys and other sources. The data were analysed, characterized and computerized to generate digital land resources database. The generated databases were stored, manipulated and geoprocessed using computer and various softwares to produce digital spatial and non-spatial information which included thematic maps for elevation, climate, length of growing period (LGP) soils and agroecological zones. Tables on land attribute database, descriptive soil legend and reports were also generated. The digital databases were then used to run a land evaluation for the area. Automated land evaluation system (ALES) was employed to compute physical land suitability evaluation for specified land utilisation types (LUTs), i.e., maize, rice, citrus and sesame. The results of the suitability evaluation showed that 57% of the area could be used to produce maize, 85% for citrus, 22% paddy and 78% sesame; with production potentials ranging from moderate to poor for all studied LUTs. The major limitations were soil erosion, limited nutrient availability, unfavourable rooting conditions and wetness. Citrus was the most suited to the area, followed by sesame, maize and lowland rice.

**Key words:** Production potential, soil erosion, nutrients

## **Land use changes due to traditional irrigation activities in Tanzania**

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Land use changes due to traditional irrigation activities was assessed in four villages around Ruaha Mbuyuni in Tanzania. Three sets of aerial photographs (1955, 1976 and 1999) were used, interpreted on a mirror stereoscope and analysed using GIS-ARC/INFO programme. The area of each class was calculated for each data set from which the rate of expansion of irrigated farms was determined. Results showed that irrigated fields expanded by 2056.8 and 1528.6 ha with expansion rates of 97.94 and 66.46 ha yr<sup>-1</sup> from 1955 to 1976 and 1976 to 1999, respectively. Human population increased from 2,886 to 16,877 people between 1967 and 1998. Irrigation activities increased the extent of socio-economic activities like firewood gathering and building. Total soil nitrogen, available phosphorus and organic matter content were low in all fields. Exchangeable Na was high in some fields potentially able to cause soil salinity and sodicity. Other soil chemical properties, i.e., pH, Ca, Mg and CEC were within the acceptable range for irrigation activities and crop productivity. Soil bulk density values were within the acceptable range for water infiltration and plant roots penetration. Soil textural classes ranged from sandy loam to sandy clay loam for the topsoil and sandy to clay for the subsoil. Generally, the results have shown that the patterns of land use changes in the study area were due to irrigation activities taking place in the area which has influenced population growth and socio-economic development.

**Key words:** Soil fertility, soil properties, water infiltration

## **Accuracy of land cover classification based on landsat thematic mapper satellite data**

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This study involved digital image processing and interpretation for land cover classification in Ngerengere watershed in Tanzania, covering about 300 km<sup>2</sup>. Land cover, which relates to the type of feature present on the surface of the earth of the study area was elaborated. The procedures involved reconnaissance survey to acquire 'a priori' knowledge about the area, unsupervised classification, supervised classification, field work for ground truthing, image rectification and restoration, and ultimately producing a land cover map of Ngerengere watershed. The remote sensing (RS) software applied was ERDAS 7.5. Overall classification accuracy (OCA) was about 70% which was below the recommended minimum level of interpretation accuracy value (85%). Although the produced land cover map had relatively low OCA, it had a good correlation with the present land use and vegetation. Further statistical analysis, by use of KHAT (K) statistics gave a value of 0.65 which was above 0.5 and approached 1.0, hence acceptance of the land cover map produced from that classification as primary data for land use planning. Chi-square (X<sup>2</sup>) distribution to test the goodness of fit of the land cover map elaborated, revealed absence of significant difference between the obtained and recommended OCA (p<0.01). In order to come up with a sustainable land use planning of the

area, other data are required. Every land cover category needed its own ancillary data which are site specific to come up with a proposal or alternatives for land use planning of an area.

**Key words:** Digital images, interpretation accuracy, land cover map

### **Impact of cereal-tobacco farming system on Miombo Woodland in Tanzania**

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A study was carried out in the cereal-tobacco farming system in Uyui District, Tabora, Tanzania to assess land use/land cover changes, as the result of cereal-tobacco farming systems and to identify socio-economic factors influencing land use changes in the cereal-tobacco farming system. The period of assessment was 27 years (1970-1997). Broad classes of land use for the years 1970, 1980 and 1997 were established through visual aerial photo interpretation, and digitized into the GIS (ArcInfo/ArcView) software for spatial analysis and map production. Participatory rural appraisal and questionnaire were used to collect socio-economic data. It was evident that there was conversion of e miombo woodlands and other forms of vegetation from higher to lower grades. Between 1970 and 1980, a closed woodland of about 1,369 0 ha (30.2%) was changed to cultivated land, 326 ha (7.2%) to bushland, and 722 ha (16%) to grassland. Between 1980 and 1997, out of 687.7 ha of closed woodland, only 48.8 ha (7.1%) remained unchanged. A total of 11,471 ha (81.3%) of the land were under cultivation up to 1997. Agroforestry was a new land use practice in 1997 and occupied 3.9% of the land. Throughout the study period, closed woodland decreased, while cultivated land continuously increased. The major factors responsible for land use/land cover changed included: shifting/rotation cultivation, continuously shortening, fallow periods and demand for fuelwood for curing tobacco. Other factors were farm expansion, growth of population and encroachment on gazetted forests.

**Key words:** Agro-forestry, closed woodland, fallowing, GIS

### **Land use assessment in reserve lands of Mboole-Muyonzo traditional system in Zambia**

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Reliable and up-to-date information about land use practices and available land resources in an area is essential for successful resource development and conservation. A land use assessment study was carried out in Mboole-Muyonzo traditional land, in Southernthern Zambia, to assess current land utilisation and management changes over 1970-1991, and 1969- 1990. From the study, human population more than doubled in the two decades (5% annual growth), cultivated land expanded by 68.4% between 1970 and 1991, cattle stocking was 2.4 ha/beast/year (i.e. 40-60% overstocking) and available grazing land was less than half the requirement. Shortage of good arable land forced the inhabitants to cultivate the hilly terrain resulting in all forms of soil erosion. Land shortage in the area was

more as a result of the 1969 coercive displacement of people to give way for the Batoka ranch project. utilisation

**Key words:** Land distribution, land tenure, soil conservation

### **Land evaluation for rainfed crops in Liti-Tengeru Farm in Tanzania**

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A detailed land evaluation using the FAO Framework and Resource Survey was carried out at Tengeru Livestock Training Institute (LITI) in Tanzania. The objectives were to: (a) test the adaptability of the 1996 FAO Framework for Land Evaluation for rainfed field crop and pastures; (b) establish the land resources inventory of the LITI farm; and (c) assess the land suitability and limitations of the major land units in the farm for different land uses. The concepts and principles in the 1976 FAO framework were found to work well in the study area. However, some of the methodologies and procedures outlined in the 1984 FAO guidelines had to be refined in order to match with the actual local conditions and crops' performance. Different approaches from those proposed in the 1984 FAO guidelines were used for assessment of moisture availability, temperature regime and soil erosion hazard. Three soil types, namely, mollic andosols, eutric fluvisols and pellic vertisols were identified in the area according to the 1988 FAO-UNESCO Legend. The major limitations in all soils of the study area were: limited moisture availability for perennial crops and pastures, nitrogen deficiency, and land degradation through soil erosion and/or soil compaction. The major limitations for using mollic andosols in land mapping unit 34B1 were severe soil erosion and buried stones, which could limit tillage using tractors. This land unit was very fertile and highly suitable for crop production. The eutric fluvisols in mapping land unit 14 C1, were also fertile and suitable for all crops and pastures. Supplementary irrigation was necessary for optimum yield of perennial crops and pastures on the farm. The pellic vertisols in land unit 11C2 was not suitable for most crop production and the pasture grasses (Siratro and nappier grass). It was, however, suitable for rhodes and buffel grass. The major limitations in using this land unit were: unfavourable soil structure and texture, poor drainage; shallow soil depth, presence of a CaCo<sub>3</sub> toxic layer below 75 cm, high sodium level, and deficiency of the major nutrient N, P and K. Economic analysis showed that pasture seeds production gave the highest farm net income in the area.

**Key words:** FAO, irrigation, farm income, pastures

### **Land use practices in a recently opened farmland and their impact on sustainable agriculture**

Mumbi, L.

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A study was conducted in the former Kamenza Forest reserve in Zambia to assess land use practices and their impact of on agricultural sustainability. The study aimed at collecting and compiling land resources data of the area and to carry out a land use classification before and after the land was opened up. Land resources were characterised in terms of climate, soil type

and nutrient status. Two sets of aerial photographs (1991) were interpreted and the results analysed using GIS-ARC/INFO to identify land use pattern before the land was opened for farming. Satellite image (1998) was enhanced in ERDAS image 8.3.1 software for visual interpretation. The result was fed into GIS-ARC/INFO to obtain the land use after the area was opened for farming. The study revealed that while climate was suitable for agricultural production, soil pH was low and ranged from 3.7-4.9. Total nitrogen, organic matter and exchangeable calcium were also deficient. Only a small portion of the total land area (8.3 to 8.5%) was used for crop agriculture before land was opened up for farming. A large part of it was under closed woodlands representing 84.2-86.5% of the total land area. Upon opening up the area for farming, the area under crop production increased to 23.5 and 25.8% of what was closed woodland, showing that there was rapid land clearing. The main farming activity was crop production (98.7%) with maize as the dominant crop (66.6%). It was also shown that there existed a problem of massive tree cutting (51.3%) and low utilisation of agricultural inputs such as lime (1.3%).

**Key words:** Climate, crops, land resources, nutrients

### **Rainwater harvesting and storage for irrigation under paddy production in semi-arid Hombolo Tanzania**

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Rainfed lowland rice production covers 75% of the total area (369 000 ha) currently under rice production in Tanzania. It is the most predominant rice ecosystem compared with others (irrigated, upland, hydromorphic and inland swamp ecosystems). The system employs simple flood water management techniques of rainwater harvesting (RWH). The RWH system has a catchment or collecting area and a cropped basin where the collected runoff is used to grow crops. The main problem with the current RWH system in Tanzania is that it is subjected to high uncertainties of rainfall amount and distribution. This study focused on evaluation of performance of surface water storage for supplementary irrigation of the paddy crop to reduce the effect of long dry spells. Results showed a significant difference in yield between with and without supplementary irrigation. RWH with storage and supplemental irrigation produced 3.2 t ha<sup>-1</sup> while RWH without storage produced 0.2 t ha<sup>-1</sup>. Thus RWH incorporating a storage reservoir for supplementary irrigation of paddy could help to stabilise yields of paddy in semi-arid areas of Tanzania.

**Key words:** Hydromorphic, inland swamp ecosystems, upland

### **Economic feasibility of rain water harvesting (RWH) for supplementary irrigation in semi-arid areas of Tanzania**

Mashinga, T.M.

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A weather driven simulation model was developed to evaluate the economic feasibility of rain water harvesting (RWH) in the farming system of semi-arid areas of Tanzania. Biophysical parameters were combined with economic parameters to determine the net benefits of RWH

system to a farmer. The model was calibrated using historical climatic data obtained from meteorological stations and the experimental site. Data were collected for three seasons between 1995 and 1999. The model revealed that the returns accrued to the resources invested could be recovered, particularly in years proceeding the initial year of investment. This was because the storage tank was a long term asset which generated continuous benefits for several years. This was predicted from the high yields obtained when harvested rain water was applied to crops compared production without RWH storage. Whereas the yields produced under catchment area ratio (CA:CF) of 4:1 and 2:1 with RWH storage were 3.92 and 2.53 t ha<sup>-1</sup>, respectively, the yields produced under catchment area ration (CA:CF) of 4:1 and 2:1 without RWH storage were 1.92 and 2.4 t ha<sup>-1</sup>, respectively. RWH system could be a break through for mitigating the long term effect of erratic and unreliable rainfall in semi-arid areas of Tanzania.

**Key words:** Catchment, evapotranspiration, run-off, soil water

### **Landsat thematic mapper and ancillary data for assessment of potential areas for rain water harvesting cropping systems in Tanzania**

Kweka, A.R.

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Rain Water Harvesting (RWH) is a system which can store and redistribute moisture for crops in areas where rainfall distribution limits dryland crop production. In regions where rainfall is insufficient to produce a crop, water harvesting offers an opportunity to bring such areas under cultivation. However, in many areas, conventional planning data for selecting sites suitable for RWH cropping system is in most cases not easily available or not up to date. This study evaluated the possibility of using satellite images to improve and up-date the required data. The study used a nested procedure, combining coverage of a small sample area by Landsat Thematic Mapper (MT) Satellite imagery, conventional photo interpretation and analysis of soil and topographic maps to identify potential areas for RWH cropping system. Computer pattern recognition techniques were used to discriminate soil information from the Landsat Thematic Mapper (TM) satellite data on a sample area. Soil mapping units from a conventional soil survey and aerial photo interpretation were matched to the classified soil spectral map for interpretation and description of the generated classes. Field investigations were done to confirm the results of the sample area which was then extended to a larger area by extrapolation using computer algorithms. Results shows that combination of Landsat TM data and ancillary data can replace extensive field surveys in identifying suitable area for TWH, especially where ground truth is available and the landscape is sparsely vegetated.

**Key words:** Dryland crops, satellite imagery, spectral map

### **Performance of physically based models in designing rain water harvesting crop systems**

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Three physically based models were used to simulate the effects of rain water harvesting on Sorghum yield in semi-arid Hombolo, Dodoma, Tanzania. The models were: Runoff estimation

model (THIRST), crop growth model (PARCH), and soil water availability model. Different components of the models relevant to rain water harvesting were combined to form a complete model to estimate runoff, soil moisture content and crop yield. Rain water harvesting with storage was simulated by supplying runoff collected and stored in reservoirs as supplementary irrigation water for days when soil moisture content was below the allowable value. There was a fairly good agreement between observed and simulated runoff for a 10 m x 20 m catchment ( $r = 0.80$ ). For a 10 m x 40 m catchment, the correlation between measured and estimated runoff was relatively low ( $r = 0.71$ ). The simulated moisture trend was the same as to the measured soil moisture ( $r = 0.61$ ). However, the model tends to overpredict soil moisture content. The trend of simulated sorghum exhibited a direct relationship of yield increase and water quantity and distribution with correlation coefficient ( $r = 0.62$ ). The model was, however, inadequate in predicting the upper limit of water input and hence the effects of water logging on crop yield.

**Key words:** Crop growth model, logging runoff, sorghum

## **Crop performance under rain water harvesting in semi-arid central Tanzania**

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Crop production in semi-arid parts of Tanzania is often limited by rain failure or short duration of rainfall. This problem could be minimised by harvesting rain water during the rainy seasons and using it for crop production when rains recede. However, rain water harvesting technology can only be adopted widely if farmers know the impact of the harvested rain water. A study was conducted to quantify maize and sorghum performance due to rain water harvesting as a supplement to rainfall in arid and semi-arid central Tanzania. An experiment was located downstream of uncultivated catchment area, with treatments in the order of catchment area of 5 m x 40 m (4:1 treatment), catchment area of 5 m x 20 m (2:1 treatment) and no catchment (0:1 treatment or control). During rain storms, runoff water was either applied directly to crops (without storage) or was stored in a small reservoir dug between the catchment area and the cropped field (with storage). Crop grown under the 4:1 treatment with storage yielded the highest in both maize ( $3.26 \text{ t ha}^{-1}$ ) and sorghum ( $3.22 \text{ t ha}^{-1}$ ), followed by the 2:1 treatment with storage ( $2.18 \text{ t ha}^{-1}$ ) for maize and ( $2.67 \text{ t ha}^{-1}$ ) for sorghum. It was clear that rain water harvesting with storage produced higher maize and sorghum yield as compared to the same treatment without storage. There was no significant difference in yield among treatments under direct application of the harvested water and that of no rain water harvesting, although crops grown under treatment of 2:1 produced relatively higher yield ( $2.14 \text{ t ha}^{-1}$ ) for maize and lowest ( $1.48 \text{ t ha}^{-1}$ ) for sorghum followed by that of area ratio of 4:1 ( $1.77 \text{ t ha}^{-1}$ ) for sorghum, whereas that of treatment of 0:1 yielded the lowest ( $1.69 \text{ t ha}^{-1}$ ) for maize and ranked the third ( $1.80 \text{ t ha}^{-1}$ ) for sorghum.

**Key words:** Maize, rainfall, rainwater, sorghum

## **Agronomic evaluation of Minjingu phosphate rock on selected Tanzanian soils**

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This study investigated the possibility of using Minjingu phosphate rock (MPR) from Tanzania as a P source for direct application using maize as a test crop. Five soils were used, four of which were acid and low in calcium and phosphorus; while the fifth had high pH and exchangeable calcium but low in phosphorus. Both soft and hard MPRs are francolites having medium and high reactivity, respectively. The acid soils tested were a Chromic Acrisol, an Umbric Andosol and a Chromic Acrisol. The high pH soil was an Eutri-Cambisol. Treatments included: a control, hard MPR, soft MPR, hard MPR+TSP, soft MPR + TSP. A single P rate was used for both pot and field experiments as follows: 160 and 320 mg P kg<sup>-1</sup> for the low to medium and very high P fixing soil, respectively. Comparable relative agronomic effectiveness (RAE) values were obtained with soft and hard MPRs for maize dry matter yield (DMY), P uptake, grain yield and P concentration. The RAE for first crop DMY and P uptake for soils treated with MPRs alone increased from 61 to 90% after mixing with TSP. The RAE for second crop DMY and P uptake for MPR treated soils was 124%, and for soils treated with MPR mixed with TSP RAE was 111%. The RAE for first, second and third year grain yields and P concentration for soils treated with MPRs were 62, 87 and 90% and improved to 101, 100 and 103% after mixing MPRs with TSP, respectively. For the high pH soil, the RAE for maize DMY increased from 11.0% (MPRs alone) to 93.0% (MPRs + TSP); while P uptake increased from 7.1% (MPRs alone) to 94.0% (MPRs + TSP). Higher quantities of labile P remaining in the soil were obtained in soils treated with TSP and MPRs mixed with TSP (127.9-141.2 mg P kg<sup>-1</sup>). Increases in soil pH (0.3 units) and exchangeable calcium (0.4 units), and a reduction of exchangeable aluminium (0.2 units) were attained in soils treated with MPRs. Hard MPR was comparable to soft MPR in agronomic effectiveness in acid soils low in calcium and phosphorus, hence, can be used for direct application to maize.

**Key words:** Chromic acrisol, phosphorus TSP, umbric andosol

## **Phosphate retention by some Tanzanian soils**

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A study was done to evaluate the retention of phosphate by four soils from Olmotonyi in Arusha region and Mzumbe, Mkuyuni and Mkata areas in Morogoro region, all in Tanzania. The four soils were classified as Vitrandept, paleustalf, Tropohumult and Pellustert, respectively. The soils' clay contents were 8.4, 36, 26 and 50%, and the dominant clay minerals were allophone-imogolite, kaolinite and poorly crystalline Al and Fe-oxyhydroxides, kaolinite and more crystalline Al and Fe-oxyhydroxides and smectites in the Vitrandept, Paleustalf, Tropohumult and Pellustert, respectively. Organic carbon were 5.81, 1.68, 4.28 and 0.78; Bray 1 extractable P were 7.50, 4.00, 162.50 and 8.00  $\mu\text{g P g}^{-1}$  soil and the pH in were 6.55, 5.40, 5.95 and 7.20 for the Vitrandept, Paleustalf, Tropohumult and Pellustert, respectively. Phosphate retention studies involved adding P at rates ranging from 0 to 2000  $\mu\text{g P g}^{-1}$  soil showed that the amounts of phosphate retained were in the order Vitrandept > Talcustalf > Pellustert > Tropohumult. The phosphate

retention maxima (b) were 1450, 1020, 780 and 769  $\mu\text{g P g}^{-1}$  soil. The bonding energies (k) were 0.17, 0.22, 0.048 and 0.14  $\text{ml}^{-1}$  for the four soils, respectively. The B – horizons retained more phosphate than the composite and A and C horizons. The amount of phosphate retained was influenced by the type and nature of the colloid fractions of the soils and their affinities for phosphate ions. Phosphate retention isotherms were of the L – type and the retention did not conform to the linear transformations of the Langmuir, Freundlich and Temkin adsorption equations. This indicated that phosphate retention constituted simple more complex reactions. Organic and inorganic anions reduced P retention. Phosphate retention increased the CEC of the soils in the order Paleustalf > Vitrandept > Tropohumult > Pellustert. Phosphate retention was not accompanied by increase in soil pH except in cases where the pH of the phosphate solutions had been adjusted to the pH of the individual soils confirming the buffer capacity of soils in the former and the displacement of OM- groups in the latter. Drying of the soil – phosphate suspension at room temperature increased P retention and this was due to increased time of contact between the phosphate and soil colloids and diffusion of the retained into the soil colloids thus creating more phosphate retention sites.

**Key words:** Allephone, kaolinite, Langmir, isotherms, vitrandept

### **Effect of boundary tree root pruning on maize and wood yield in western Kenya**

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A farmer-survey and two field experiments were carried out at Siaya and Nyabeda in western Kenya to investigate the effect of carp on boundary tree growth soil water dynamics, maize and wood yield. The experiment carried out at Siaya included 4 years old trees of *Casuarina equisetifolia*, *Eucalyptus grandis*, *Grevillea robusta* and *Markhamia lutea*. The one at Nyabeda involved 5 years old *G. Robusta*. Results from the Siaya survey showed that 74% of the farmers grew *M. Lutea*, which is an indigenous tree spp in western Kenya. Eightyfour percent of the respondents observed that crop yields close to the trees were very low compared to far away from the trees. All the four tree species in both sites survived heavy crown and root pruning without mortality or reduced growth. Tree species showed significant ( $p < 0.001$ ) variability in branch biomass produced from crown pruning at Siaya. *Eucalyptus grandis* had the the highest biomass ( $107.2 \text{ kg tree}^{-1}$ ) at the time of first pruning; while *M. lutea* had the lowest ( $5.5 \text{ kg tree}^{-1}$ ). New branch sprouts of pruned trees continued to grow in length and diameter. *Eucalyptus grandis* had the highest growth in both new branch, length and basal diameter (10.49m and 13.44 cm, respectively; while *M. lutea* had the least (5.39 m and 4.75 cm, respectively). Transpiration of crown and crown plus root pruned *C. equisetifolia* and *Grevillea robusta* trees was reduced by 50% compared to unpruned trees. Maize grain yield was positively influenced by photosynthetically active radiation under both *C. equisetifolia* ( $R^2=0.84$ ) and *E. grandis* ( $R^2=0.97$ ) boundary trees.

**Key words:** Carp pruning, *Eucalyptus grandis*, *Markhamia lutea*

### **Soil moisture dynamics and performance of of *Tefrosia vogelii* and maize relay intercropping in semi-arid Tanzania**

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A study was conducted on the effect of time of planting and spacing of *Tephrosia vogelii* on soil moisture and performance of relay intercropping with maize, at Gairo Tanzani. Treatments include time of planting at 0, 2 and 4 weeks after maize; spacing at 30 x 90 (Tv30), 60 x 90 (Tv60) and 90 x 90 (Tv90) cm (intercrop and monoculture *Tephrosia vogelii*) plus control (Tv0). Other treatments included: without and with half and full recommended doses of nitrogen and phosphorus, respectively. Highest soil moisture and maize yield were maintained with Week 2 Tv60 in the first season. At three months in the intercrops, total shrub biomass was significantly higher ( $p < 0.05$ ) in Week 2 Tv30 than for other periods. Total shrub yields at 11 months in monoculture were 2-6 times higher than in the intercrops. Increment in shrub biomass height and diameter were significantly higher ( $p < 0.05$ ) in Week 0Tv90 than the rest between 6 and 11 months in intercrops. Maize yield was maximised with fertilised monoculture *Tephrosia vogelii*, unfertilised intercrops recorded 50 and 58% increase over unfertilised Tv0 in second and third seasons, respectively.

**Key words:** Monoculture, nitrogen, phosphorus, *Tephrosia vogelii*

### **Forest site productivity in Kilombero Valley Teak plantation in Tanzania**

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Teak was first introduced in Tanzania in 1902 by the Germans ansto-date there are two public plantations at Mtibwa and Longuza and one private plantation at Kilombero (KVTC), covering a total of 9,772 hectares. Success of forest plantation establishment and growth depends on availability of growth requirements. This study was conducted to investigate how well site and stand factors can be used to distinguish among site productivity classes for *Tectona grandis* at KVTC plantation in Tanzania. Fourty eight paired sample plots were selected from teak plantation and adjoining natural forest, from which 96 soil samples were collected for physical and chemical analyses. Soil organic carbon, bulk density, clay and sand content, textural class, soil colour and mottling were significantly different between site classes soil pH, silt content and, slope and elevaltun were not significant ( $p < 0.05$ ) and did not correlate well to teak height growth. Soil mottling, top-soil colour, percent silt content, subsoil organic carbon, were soil properties singled out in multiple regression as factors that best discriminate site quality classes for teak in KVTC plantation.

**Key words:** Bulk density, mottling, soil colour, *Tectrona grandis*

### **Seasonal variations in nitrogen transformation in soils from two agro-ecological zones in Morogoro, Tanzania**

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Seasonal variations of various forms of nitrogen in soil representing two different agro-ecological zones in Morogoro Region (Melela and Tandai) were studied by sampling soils at different seasons. Available N varied widely with season and constituted only a small portion (< 4%) of total N. The pattern and magnitude of seasonal variations were different in the two zones and appeared to be related to soil moisture. Acid hydrolysis revealed that total hydrolysable-N, unhydrolysable-N and ammonium, amino acid, hexosamine, hydroxyamine, identified and unidentified N fractions, expressed as percentages of total soil N, varied with season, but the variations were different for different fractions. Throughout the experimental period, amino acid-N accounted for the largest portion of the identified N fraction, whereas hydroxyamine-N constituted the smallest proportion.

**Key words:** Amino acid, hydrolysable –N, hydroxylamine

### **Value of organic activators in the composting of cereal residues in Tanzania**

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The effects of organic activators, cattle manure and legume (bean) residues, on composting rate and quality of maize straw were investigated in pits in Tanzania. Addition of organic activators markedly increased the decomposition rate of the maize straw. The increase in the decomposition rate corresponded well to increase in temperature and number of mesophilic and thermophilic bacteria and actinomycetes. Compost from activated straw was of better quality than that from straw alone. Activated compost had better physical properties (black colour, earthy odour, granular and fluffy structure), narrower C/N ratio, higher organic matter content, slightly alkaline pH, higher total N and total inorganic N. Most of the inorganic N was in the ammoniacal form. In all aspects, the manure-activated straw performed better than the legume activated straw. Increasing the proportion of bean residue in the compostable mixture is suggested as a possible way of increasing the performance of the legume activated straw.

**Key words:** Cattle manure, legume, mesophilic, thermophilic

### **Minjingu Phosphate Rock as a source of phosphorus for maize when applied in combination with manures**

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Experiments were carried out to evaluate the effects of compost and farmyard manure (FYM) on plant availability of P from Minjingu phosphate rock (Minjingu PR). The experiments included

an incubation, pot and field experiment, and were conducted on an Ultisol of pH of 4.4 in 0.01 M CaCl<sub>2</sub> and a Bray 1 extractable P content of 5.60 mg P kg<sup>-1</sup> soil. Treatments in the incubation study included Minjingu PR (400 mg P kg<sup>-1</sup> soil) applied alone and in combination with compost or FYM at 5 tonnes ha<sup>-1</sup>. The treated soils were incubated for up to 90 days at field capacity. Organic materials, particularly FYM enhanced the dissolution of Minjingu PR. After 60 days of incubation, excluding the P contribution of the organic materials, Minjingu PR in combination with compost raised 58 mg P kg<sup>-1</sup> soil, Minjingu PR in combination with FYM, 74 mg P kg<sup>-1</sup> soil compared to only 45 mg P kg<sup>-1</sup> when Minjingu PR was applied alone. Treatments in the pot study consisted of 0 and 40 kg P ha<sup>-1</sup> as Triple superphosphate (TSP); 40, 120 and 200 kg P ha<sup>-1</sup> as Minjingu PR and combinations of FYM and compost at 5 and 10 tonnes ha<sup>-1</sup> with 40 kg P ha<sup>-1</sup> as Minjingu PR. The same treatments were applied in the field study except that the 10 tonnes ha<sup>-1</sup> rate of FYM and compost application was dropped. Results of the pot study showed that TSP significantly increased extractable P, dry matter yield and P uptake. Minjingu PR alone also increased extractable P and dry matter yield but to a lesser extent than TSP. Increasing the rate of Minjingu PR from 40 to 200 kg P ha<sup>-1</sup> resulted in further, but marginal increase in dry matter yield and P uptake. Application of Minjingu PR together with compost significantly increased extractable P above the Minjingu PR (40 kg P ha<sup>-1</sup>) treatment. Phosphorus uptake and dry matter yields were, however, depressed. Farmyard manure (5 tonnes ha<sup>-1</sup>) significantly enhanced the agronomic effectiveness of Minjingu PR as reflected by significant increases in extractable P, dry matter yield and P uptake. FYM to enhance the dissolution of Minjingu PR in the test soil. Application of FYM at 10 tonnes ha<sup>-1</sup> did not further enhance the agronomic effectiveness of Minjingu PR.

**Key words:** Dry matter yield, ultisol

### **Comparative evaluation of techniques for soil erosion assessment in field plots in Tanzania**

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Four techniques for assessing soil erosion were evaluated in field plots in bare-fallow as well as in plots under maize-cowpea sequence for two consecutive seasons, at IITA, Ibadan, in Nigeria. The techniques assessed were: Tracer, (Aluminium Paint), Nails (16 and 25 nails per plot), Rill and Universal Soil Loss Equation (USLE). Soil loss measured by the conventional runoff plot technique was used for determining the influence of the various techniques on the magnitude of soil erosion. The Tracer technique was discontinued before the end of the study because it was difficult to accurately monitor the movement of the sprayed paint particles. The techniques had no significant influence ( $p > 0.05$ ) on the magnitude of soil loss and did not interfere with erosional processes. There was significantly more soil loss ( $p < 0.01$ ) in bare-fallow than in cropped. In the first season, soil loss from bare-fallow plots was 153.3 t ha<sup>-1</sup> compared to only 40.2 t ha<sup>-1</sup> in plots under maize. In the second season, bare-fallow plots lost 87.5 t soil ha<sup>-1</sup> compared to 39.4 t ha<sup>-1</sup> from plots under cowpea. Maize and cowpea reduced the amount of soil loss by 3.8 and 2.2 times, respectively. There was more deterioration of soil physical conditions in bare-fallow than in plots under a maize-cowpea sequence. There was a significant increase in dry bulk density in bare-fallow plots whereas the increase was non-significant in plots cropped to a maize-cowpea sequence. During the same period, cumulative and equilibrium infiltration rates fell by 41 and 37%, respectively, in bare-fallow plots compared

to an increase (improvement) of about 26 and 37%. There was no significant difference between soil loss determined by the 16 nails or 25 nails and conventional runoff plot technique. Also, soil loss determined by 16 nails did not differ significantly from that determined by the 25 nails technique. Soil loss determined by rill technique on size plots (3 bare-fallow and 3 plots with maize at the end of the first season, was significantly lower than that measured by the conventional runoff plot technique. The USLE significantly ( $p < 0.01$ ) underestimated soil loss. Soil loss estimated by the USLE in the first season respectively for 11 and 8% slope was 128.8, 144.3 and 85.9 t gha<sup>-1</sup> compared to 167.6, 156.1 and 136.3 t gha<sup>-1</sup> measured by the conventional runoff plot technique.

**Key words:** Aluminium paint, nail technique, USLE

### **Evaluation of soil test methods for estimation of available phosphorus in soils of Mbeya Region, Tanzania**

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A study was undertaken to evaluate the suitability of Bray and Kurtz I (BK I) Bray and Kurtz II (BK II), Olsen's and Mehlich's P extractants, and the P-adsorption isotherms in an attempt to identify the extracting agent which can be used as the basis for P fertiliser recommendations for ten soils from Mbeya Region, in Tanzania. Hybrid maize (*Zea mays* L.) (H 6302) was used as the test crop in a glasshouse pot experiment and P was applied at the rates of 0, 3.5, 7.0 and 14 x 10<sup>-2</sup> g P 3.5<sup>-1</sup> kg soil (per pot). Simple linear correlation and the graphical and mathematical critical level techniques of Cate and Nelson were used in selecting the best P availability index. The amounts of P extracted by the four extractants increased significantly with levels of added P, but the increases were very variable between soils. The amounts extracted by the four extractants were in the order of Mehlich's > Olsen's > BKII > BKI. Highly positive correlation between dry matter yields, percent P contents, P uptake and the soil P-test values were obtained. Based on the R<sup>2</sup> with the relative yields and P uptake, the Olsen's extractant proved to be somehow superior to the others. The critical soil test values for the BKI, BKII, Olsen's and Mehlich's extractants were 4.35, 15.30, 34.60 and 54 ppm P, respectively; while the critical P content in the plants was 0.13 percent. The P-adsorption isotherms greatly over estimated the amounts of P to be added for the soils under study, but were useful in characterising the P adsorption capacities of the soils. It was concluded that the Olsen's extractant be adopted for the estimation of plant available P for the soils investigated subject to field experimentation to confirm its superiority over the others.

**Key words:** Bray 1 and II, Olsen -P, Mehlich -P, sorption isotherms

### **Plant-water and maize grain yield in relation to soil water at Morogoro, in Tanzania**

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Analysis was made of reference crop evapotranspiration (ET<sub>o</sub>) and rainfall (R) data on a 10-day basis over a 10-year period (1973/74-1982/83). On the average, ET<sub>o</sub> exceeded R during the

entire shortrain season, thus masking production of crops other than those tolerant to water stress. Katumani and Ilonga composite maize (*Zea mays* L) cultivars with different maturation periods were grown under rain-fed condition and under limited irrigation. High values of weighted soil matric potential ( $Y_m$ ) were associated with high water holding capacity (WHC) of soil. In all treatments,  $Y_m$  values declined near tasselling stage due to high demand for water which increased with the approach of physiological maturity. Averaged over all the seasons, leaf water potential ( $Y_1$ ) was 2.22 bars higher in soil 1 (high WHC) than in soil 2 (low WHC). Katumani had  $Y_1$  of 3 bars higher than Ilonga Composite. Plants had  $Y_1$  4.0 bars higher under limited irrigation than under rainfed conditions on the average. Plants of Ilonga Composite were 16.4% taller, had stems 25.4% thicker and 2 more leaves that were 55.9% larger than those of Katumani. Leaf area index was significantly increased by irrigation and was 79% higher for Ilonga Composite compared to Katumani. Root length density (RLD) was 42% higher in Soil 1 than in Soil 2 with Ilonga Composite having RLD 10% higher than Katumani. At 54 DFP, irrigation significantly increased DM yield by 92 and 46% for Ilonga Composite and Katumani, respectively compared rainfed conditions. All factors studied had significant effect on grain yield. In Soil 1, grain yield was 1,322.1 kg ha<sup>-1</sup>, 18% more than that in soil 2 on the average. Ilonga Composite gave 1,410.9 kg ha<sup>-1</sup> of grain, 37% more than Katumani. Total water use efficiency (TWUE) values for both DM and grain yield were higher in Soil 1 than in Soil 2 on account of WHC. Ilonga Composite had TWUE (DM) values ranging from 1.3 to over 2.0 times greater than those for Katumani in the two water regimes. Irrigation increased TWUE (DM) for both cultivars.

**Key words:** Evapotranspiration, irrigation, matric potential, *Zea mays*

### **Effect of maize straw on availability of soil and fertiliser nitrogen and phosphorus, and maize yield in Tanzania**

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The effect of maize straw on the availability of soil and fertiliser N and P, and maize yield were studied in a glasshouse and under field conditions. Treatments in the glasshouse were rate, time and grade of straw applied to soil with or without fertiliser N and P. The straw rates tested were 0, 2.5 and 5 t ha<sup>-1</sup>, the times of straw application were 4 weeks before planting or at planting. The straw grades were fine (straw particles of 2-12 mm) or coarse (straw particles of 13-50 mm). In the field, only the rate (0, 5, and 7 t ha<sup>-1</sup>) and method of straw application (surface placement or incorporation) were studied. Under glasshouse and field conditions, the contents of available N, extractable – P and their concentrations in the plants, decreased consistently with increasing rates of straw application. Dry matter yield and grain yield also decreased consistently with increasing rates of straw application. Available nitrogen and extractable-phosphorus in the soil were significantly higher when straw was applied at planting than when applied to continuously dry or moist soil. The contents of available nitrogen in the soil, total N in the plants and grain yield maize were significantly higher when straw was surface-applied than when incorporated into the soil.

**Key words:** Available nitrogen, extractable phosphorus

## **Plant-water and sorghum grain yield in relation to soil water at Morogoro, Tanzania**

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A field experiment was conducted at the Sokoine University of Agriculture Experimental Farm to study plant-water status and grain yield of sorghum (*Sorghum bicolor* (L.) Moench) in relation with soil-water status. Treatments consisted of two soils, one with high water holding capacity (Soil 1), the other with a low water holding capacity (Soil 2); and two sorghum cultivars, namely, Serena improved) and Mbangala (local) under two moisture regimes of limited irrigation and rainfed conditions. Plants grown in Soil 1 showed higher leaf water potential (YL) than those in Soil 2 throughout the measurement period. Mbangala maintained a higher YL than Serena with values of -5.42 and -7.51 bars, respectively. The irrigated plants had higher YL than those under rainfed conditions. The weighted matric potential (Ym) was lower in Soil 2 than in Soil 1, the averages for the entire season -0.29 and -0.38 bars for Soils 1 and 2, respectively. The plots planted with Mbangala showed lower Ym than those with Serena (-0.34 and -0.33 bars, respectively). Plant height in Soil 1 exceeded that in Soil 2 by 24.5 cm ( $p < 0.01$ ). Significantly ( $p < 0.05$ ) higher values of LAI were produced by plants growing in Soil 1 compared to those growing in Soil 2 by a factor of 0.9. Soil 1 plants exceeded those in Soil 2 in DM by 2700 kg DM per hectare. Soils types had no significant effect on grain yield, though Serena produced significantly ( $p < 0.05$ ) higher grain yield than Mbangala. Soil 1 showed higher TWUE than Soil 2 Soil 2 gave a TWUE value of 233.5 kg DM per hectare-cm of water, while Soil 1 was 108.6. Serena showed higher TWUE than Mbangala, having values of 85.15 and 56.90 kg DM per hectare –cm of water, respectively. Total water use efficiency was higher under irrigated than rainfed conditions, by 24.3%.

**Key words:** Water potential, water use efficiency

## **Assessment of copper and zinc status of some soils of Iringa District in Tanzania**

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The objective of this study was to generate more information on copper and zinc status in soils of Iringa district in Tanzania and to select suitable extractant(s) for assessing available fractions of these nutrients. Two sets of the soils were selected from 21 soils of Iringa district for glasshouse studies. Two glasshouse studies (one for each element) were conducted on the two sets of soils using maize (*Zea mays* L., var. Ilonga composite) as the test crop. The soils were treated with 0 and 5 kg ha<sup>-1</sup> of copper in the first study and with 0 and 5 kg zinc ha<sup>-1</sup> in the zinc trial. Three extractants, viz: 0.01M EDTA, 0.005M DTPA and 0.1N HCl were used to extract the available copper and zinc in the soils. Copper and zinc application increased dry matter yields in only 4 and 8 out of the 10 soils tested, with increase of 3.6 to 16.9% for the copper trial and by 3.10 to 21.20% for the zinc trial. Application of either copper or zinc significantly increased tissue contents of these nutrients. Copper content ranged from 3.3. to 12.5 ppm in the controls and from 5.0 to 25.0 ppm in the copper treated soils. The critical copper concentration in maize tissue was 6.30 ppm. The tissue zinc concentration ranged from 38.5 to 66.5 ppm and

from 45.0 to 156.0 ppm in the controls and in the zinc treated soils, respectively. All these values were above critical concentration range, reported in the literature. The 0.01M EDTA-extractable copper content in the 61 soils ranged from 0.12 to 32.70 ppm, while the 0.1N HCl-extractable zinc ranged from 0.14 to 27.30 ppm.

**Key words:** DTPA, EDTA, HCL, partially acidulated, *Zea mays*

### **Minjingu phosphate rock products as source of phosphorus for maize and sorghum in soils of Tanzania**

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Experiments were conducted to evaluate the effectiveness of partially acidulated (PAPR) and non-acidulated Minjingu phosphate rock (PR) as sources of phosphorus for maize and sorghum. Pot and field experiments were conducted using kwa Sadala, Mlama, Mafiga, Magadu and University Gate soils. All the P carriers increased yields in Mlama Magadu and University Gate soils. The kwa Sadala and Mafiga soils, with high available P and nearly neutral pH values, did not respond to the P sources. The initial pot results indicated that the PAPRs and the non-acidulated PRs had fertiliser values nearing those of TSP in Mlama soils. In the Magadu and University Gate soils the PAPRs and PRs were generally inferior to TSP. Generally, the PAPRs and PRs had superior residual effectiveness compared to TSP in Magadu, Mlama and University Gate soils. Minjingu PR products may be effective sources of P for the Mlama, Magadu and University Gate soils and, possibly, in other soils with similar properties.

**Key words:** Phosphorus carriers, triple superphosphate

### **Boron status of soils of Iringa District in Tanzania**

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A glasshouse study was conducted to assess the boron status of soils of Iringa district in Tanzania in areas commonly used for growing maize and tobacco. Ten soil samples from 6 villages were collected for the glasshouse study, while 48 soils were collected from other villages for Hot Water Soluble Boron (WSB) assessment in the whole district. Two experiments were conducted using maize – Ilonga composite variety as a test crop. Hot water soluble boron in the tested soils ranged from 0.02-0.40 ppm and was highly correlated with pH ( $r = 0.81$ ,  $p < 0.01$ ) and organic matter content ( $r = 0.76$ ,  $p < 0.05$ ), but not with texture. Plants growing in soil with  $< 0.21$  ppm HWSB were associated with mild symptoms of B deficiency and responded slightly to B fertilisation. However, the increase in yield due to B was not significant. All tested soils produced relative yield  $> 80\%$ . The critical B concentration in the soil was estimated by the Cate and Nelson procedure and was found to be 0.21 ppm HWSB. Hot water soluble boron was highly correlated with B uptake by plants ( $r = 0.85$ ,  $p < 0.01$ ) suggesting that HWSB was a good estimate of B availability to plants. By the same procedure, the critical B concentration in the plant was 12.63 ppm. The HWSB data for all the soils was grouped into B fertility categories on the basis of soil B critical concentration and relative yields from the glasshouse

study. This resulted into two B fertility categories viz: medium and high. The medium B fertility category counted for 22% of the soils, while the rest fell in the high B fertility category.

**Key words:** Deficiency symptoms, hot water soluble boron

### **Soil fertility status of major rice-growing areas of Zanzibar Island**

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A study was conducted to characterise the fertility status of soils of the three major rice-growing areas of Zanzibar Island, namely, Bumbwi Sudi, Cheju and Kilombero in Tanzania. The soils of Bumbwi Sudi, Cheju and Kilombero were classified as Gleyic Luvisol, Dystric Vertisol and Ferric Acrisol, respectively, using the FAO-UNESCO System. According to the US Soil Taxonomy, the soils of Bumbwe Sudi and Kilombero were classified as Typic Hapludalf, while those of Cheju were Aqueptic Chromudert. Nitrogen and available phosphorus were the most limiting nutrients for rice production in all areas. A high level of exchangeable aluminium was a constraint to rice production in Cheju and Kilombero areas. Dry matter yield, plant N concentration, N uptake and grain yield showed significant ( $p < 0.01$ ) response to applied N. The increase in rice grain yield due to P application was, however, not significant. Soil pH, total N, available P and calcium contents in the soils showed significant ( $p < 0.01$ ) increased as a result of liming. Liming had a depressing effect on  $Al^{3+}$ ,  $K^+$ ,  $Mg^{2+}$ ,  $Zn^{2+}$ ,  $Fe^{2+}$  and  $Mn^{2+}$  both in soils and plants.

**Key words:** Available phosphorus, liming, nitrogen, Tanzania

### **Soil fertility constraints to bean production in Lushoto District and their amelioration using inorganic inputs**

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Investigations were conducted using soils of Lushoto District in Tanzania to assess soil fertility constraints to bean production. The investigations involved evaluation of nutrient status of selected soils from all agro-ecological zones in the district. Then three glasshouse experiments were conducted to assess the effects of liming, P sources and rates and K rates on bean yield and plant nutrient contents. The first experiment tested two levels of lime in combination with P from two sources. In the second experiment, five rates of P viz: 0, 20, 40, 60 and 80 mg kg<sup>-1</sup> from TSP and MPR were used. The third experiment tested five rates of K viz: 0, 12.5, 25, 37.5 and 50 mg kg<sup>-1</sup> soil. The chemical analysis results indicated P, N and K to be the major soil fertility constraints in the district. There were also indications that Ca could be limiting in strongly acid soils. The glasshouse experiment confirmed the need for P. three out of four soils, which had low P, gave significant increases in seed yield as a result of P application. The rates giving the highest yield were different for different soils and P sources, but ranged from 60-80 mg kg<sup>-1</sup>. TSP was superior to MPR in most soils, except in strongly acid soil, where they were comparable. In the K experiment, only one soil gave a significant increase in seed yield as a result of K application. However, K application increased yield slightly in all soils

with low K, suggesting that K was beneficial. Liming significantly increased DM yield, Ca concentration and uptake, but did not increase seed yield significantly.

**Key words:** Liming, Minjingu, nitrogen, phosphorus, potassium

### **Genotypic variation in phosphorus requirement and utilisation in nodulated common beans**

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A study to investigate the genotypic variations in phosphorus requirement and utilisation by four common bean (*Phaseolus vulgaris* L.) genotypes AA/2/5/6xK-2; 86EP 5091-B-2; EP 3-2 and Selian wonder, referred to as C<sub>2</sub>, C<sub>4</sub>, C<sub>5</sub> and C<sub>8</sub>, respectively, inoculated with a locally produced *Rhizobium* strain, PV1, was carried out at the Sokoine University of Agriculture, Morogoro, Tanzania in a glasshouse pot experiment. The soil used was an Oxic Haplustult with low levels of total nitrogen and Bray-1 extractable phosphorus. The levels of phosphorus applied were 0, 5, 10, 20, 40, 80, 120 and 160 mg P kg<sup>-1</sup> soil as KH<sub>2</sub>PO<sub>4</sub>. There were significant (p<0.05) differences of P application on the increases in the number of nodules, nodule weight, shoot and root dry weights, pod production, seed production, N and P in the shoots. These plant parameters were positively and significantly correlated with one another, suggesting the vital role of phosphorus in symbiotic nitrogen fixation. The variations in phosphorus requirement and utilisation based on the above plant parameters were attributed to the inherent genetic characteristics of the four common bean genotypes. The genotypes most tolerant to low levels of Bray-1 extractable phosphorus fixed more nitrogen symbiotically and accumulated more dry matter. The genotypes' tolerance to low levels of extractable phosphorus followed the order of C<sub>5</sub> > C<sub>4</sub> > C<sub>2</sub> > C<sub>8</sub>. The ability of the genotypes to form nodules, hence, fix nitrogen, when inoculated with the *Rhizobium* strain PV1 indicate the ability of the *Rhizobium* strain PV1 to tolerate low levels of Bray-1 extractable phosphorus. Genotypes C<sub>5</sub> and C<sub>4</sub> inoculated with *Rhizobium* strain PV1 can be grown in soils deficient in available phosphorus without any effect on reducing seed yield.

**Key words:** Bray I, *Phaseolus vulgaris*, symbiotic nitrogen

### **Decomposition of *Crotalaria* and *Leucaena* green manures and nutrient release patterns**

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The decomposition of *Crotalaria ochroleuca* and *Leucaena leucocephala* green manures, contained in litter bags and placed on the surface or buried into the soil (8-10 cm), was studied during 12 weeks of incubation in Tanzania. The study was conducted under laboratory conditions to determine decomposition and nutrient release patterns of the two green manures. The effect of method of green manure application on decomposition and subsequent nutrient release was investigated. Generally, decomposition was fast during the first six weeks of incubation and slowed down thereafter. The rate of decomposition was similar in both green

manures, which decomposed by almost 50 and 70% after six and 12 weeks of incubation, respectively. Both manures had similar nutrient releasing capacities, however, soil incorporated manure decomposed faster and released more nutrients than surface-applied manure.

**Key words:** *Clotalorria ochroleuca*, *Leucaena leucocephala*, microbial number

### **Phosphate retention of soils with high variable charge from Tanga in Tanzania**

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A laboratory study conducted one phosphate retention and the effects of retained P on pH, CEC, AEC and ZPC of three soils, namely Rhodic Kandustox, Rhodic Haplustox and Typic Haplustox from Tanga, in Tanzania. These highly weathered and leached soils have high contents of variable charge on colloids (VCS) dominated by kaolinite and iron and aluminium oxides. They possess low to very low pH, low CEC ( $<10 \text{ C mole kg}^{-1}$  soil) and aluminium saturation between 15 to 25%. The P retention capacities ranged from 1000-1400 mg P  $\text{kg}^{-1}$  in the order Rhodic Kandustox  $<$  Rhodic Haplustox  $<$  Typic Haplustox. There were high and positive correlations between the amounts of P retained and the contents of iron and aluminium oxides, and the 1:1 layer silicates. The P adsorption data did not conform to the linear transformations of the Langmuir and Freundlich equations. Additions of up to 1600 mg P  $\text{kg}^{-1}$  to the soils significantly increased the pH of the Rhodic Kandustox, Typic Haplustox and Rhodic Haplustox by 0.1, 0.4 and 0.05 units, and the CEC by 103, 66 and 61%, respectively. Phosphorus retention by the soils at 1600 mg P  $\text{kg}^{-1}$  soil reduced the AEC and lowered the ZPC of the Rhodic Kandustox, Rhodic Haplustox and Typic Haplustox by 1.80, 1.10 and 0.55 pH units, respectively. The resultant increases in pH and CEC with P retention appear to be very small in relation to the large amounts of P added to the soils.

**Key words:** AEC, CEC, Langmuir, pH, ZPC

### **Physico-chemical and biological properties of atrazine in soils in Tanzania**

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The physico-chemical and biological properties of atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) in soils were investigated in Tanzania. The batch suspension method was used for the adsorption/desorption properties of atrazine. The amount of atrazine absorbed or desorbed varied with soil properties. The adsorption data fitted the Freundlich model, Freundlich "K" values describing the adsorptive capacities of the soils varied with the inherent soil properties. Over 70% of the adsorbed atrazine was found to be desorbed after five desorption cycles. Bacteria, *Azotobacter*, *Beijerinckia* and nitrifiers were tolerant to atrazine at the concentrations tested. The population and the activities of these organisms were only slightly and temporarily affected.

**Key words:** Adsorption desorption, batch suspension method

## Potential of *Sesbania rostrata* green manure in rice production in Tanzania

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The potential of *Sesbania rostrata* as a green manure for rice production was evaluated in two experiments at Morogoro in Tanzania using a sandy clay (Vertic Ustifluent) soil. *Sesbania* plants were raised both under flooded/waterlogged paddy and drained conditions for 60 days. The effect of inoculating with *Rhizobium* either the seeds, seeds + stems, or stems alone were studied. The plant's manurial effect in terms of nitrogen release under flooded and drained soil conditions were studied. A 45-day old *S. rostrata* green manure (93.26% N) was incubated in soil at 0, 10, 20 and 30 t ha<sup>-1</sup> and the nitrogen release patterns studied for a period of 28 days. *Sesbania rostrata*, generally, grew in both soil moisture regimes. Biomass and nitrogen accumulation were in favour of drained soils up to 45 days, and, thereafter, flooded soils due to infestation by nematodes in drained soils. Inoculation increased root and/or stem nodulation, plant biomass, and N<sub>2</sub> fixation. No significant differences were observed between inoculation techniques. The equivalent of up to 20 and 34 t ha<sup>-1</sup> green biomass and 97 and 200 kg N ha<sup>-1</sup> were recorded in 45 and 60 days, respectively. On decomposition, no differences were observed between flooded and drained soils in terms of soil total N. Available N released was substantial but significantly more in flooded soils where NH<sub>4</sub>-N dominated than in drained soils dominated by NO<sub>3</sub>-N. Higher levels of green manure released higher amounts of N. The larger amounts of N accumulated by the plants, and the substantial amounts of mineralised N during the green manure decomposition in the soils, qualify *S. rostrata* as a potential biofertiliser in rice production.

**Key words:** Drained, flooded, inoculation, nodulation, rhizobia

## Concentration of lead in industrial effluent, and adsorption by soil and uptake by maize

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This study involved evaluation of lead (Pb) concentrations of the industrial effluent, Pb content in soil and maize (*Zea mays* L) plant leaves in the vicinity of a Pb battery industry in Dar es Salaam, Tanzania. Effluent, soil and plant leaves from the Pb-battery industrial compound contained Pb levels of up to 8.97 x 10<sup>5</sup>, 1.28 x 10<sup>4</sup> and 2.34 x 10<sup>3</sup> mg Pb g<sup>-1</sup> respectively, indicating high pollution of the industry premises with Pb. The Pb adsorption isotherm for the Oxic Haplustult was of L-type curve indicating a high affinity for Pb by the soil. The adsorption of Pb by an Oxic Haplustult conformed to both Langmuir and Freundlich adsorption plots, with a P value of 1128.7 mg g<sup>-1</sup> indicating high affinity. The binding energy (K) for the Langmuir equation was 2.38-ml mg<sup>-1</sup> and the values of the constants n and K for the Freundlich equation were 1.52 and 754.4, respectively. The uptake of Pb by maize grown on an Oxic Haplustult was low but increased with increasing soil Pb. The Pb uptake in the highest treatment of 200 was 2.052 mg Pb per pot (4 kg soil) and for the zero treatment was 0.29 mg Pb per pot. There was a significant (p<0.05) increase in Pb uptake with Pb application.

**Key words:** Adsorption, Langmuir, Pb uptake, *Zea mays*

## Effect of soil erosion and management practices on soil productivity in Tanzania

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A study was conducted at Sokoine University of Agriculture, in Morogoro, Tanzania, to evaluate the effect of soil erosion on soil productivity under different management practices. Treatments consisted of bare fallow (BF), permanent grass (GP), flat cropping (CP), ridge cropping (RC), fine mesh (FM), medium mesh (MM), and coarse mesh (CM). The FM, MM and CM were simulated canopy covers with net shading rates of 80, 55, and 40 percent, respectively, stretched 40 cm above the surface. Runoff ranged from 143.9 m<sup>3</sup> ha<sup>-1</sup> in the GP to 2398 m<sup>3</sup> ha<sup>-1</sup> in the BF. Runoff values from the BF, GP, CP, and CM were significantly different ( $p < 0.05$ ) among themselves and from all other treatments. Soil loss was between 0.09 t ha<sup>-1</sup> in the GP and 12.49 t ha<sup>-1</sup> in the CP. There was no significant difference in soil loss between BF and CP treatments, but they differed significantly from all other treatments. Organic carbon decreased significantly in the final soil samples in the BF, GP, RC, and FM treatments, while total N (TN) decreased significantly ( $p < 0.05$ ) in the CP, RC and CM treatments. Likewise, available phosphorus was significantly lower in the final soil samples in the GP, CP and FM. Surprisingly, both Na<sup>+</sup> and CEC were significantly higher in the final soil sample in some of the treatments.

**Key words:** Available P, runoff, soil loss, total N

## Decomposition and nutrient release patterns of *Sesbania sesban* and Black jack in Tanzanian soils

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A study was conducted to assess the decomposition and nutrient (N and P) transformation patterns of *Sesbania sesban* and Black jack (*Lantana camara*) green manures under glasshouse conditions. Then, the effect of *Lantana* with or without urea on vegetable (kale and amaranth) production was evaluated in the field. In the glasshouse experiment, the effect of two rates of application, for each manure (equivalent to 3.75 and 7.5 t ha<sup>-1</sup> for *Sesbania* and 2.75 and 5.5 t ha<sup>-1</sup> for *Lantana*) was studied in soil contained in wooden troughs. The above rates were expected to supply 60 and 120 kg N ha<sup>-1</sup> assuming complete decomposition. The plant materials were put in litter bags, incorporated at 10 cm depth and incubated at field capacity moisture for 12 weeks. In the field experiment, 556 g m<sup>-2</sup> (equivalent to 5.5 t ha<sup>-1</sup>) of *Lantana camara* green manure were incorporated at 10 cm depth with or without inorganic N fertiliser (urea) at 0, 30, 60, 90 and 120 kg N ha<sup>-1</sup>. The control plots had no inorganic fertiliser or manure. The plots (3 m x 3 m) were subdivided into two, one half planted with kale (*Brassica oleracea* var *acephala*) and the other half with amaranth (*Amaranthus* sp). The *Sesbania* decomposed significantly ( $p < 0.5$ ) faster than *Lantana* and generally exhibited net N release and net P immobilisation. *Lantana* showed net N and P immobilisation. Generally, the rate of application did not affect the decomposition and nutrient release patterns for both manures over the entire incubation period. The manured soil consistently had higher microbial counts than the control soil. Soil under *Sesbania* green manure stimulated a significantly ( $p < 0.05$ ) higher microbial count than soil with *Lantana* green manure. Overall, neither fertiliser N nor *Lantana* green

manure used singly had any definite and consistent effects on the yield of the vegetables. However, *Lantana* tended to depress yield for both vegetables. Green manure also depressed total N in kale; through the opposite was true for amarantha.

**Key words:** Amaranthus, kale, *Lantana camara*, nitrogen

### **Zinc status in soils and tea response to added zinc in selected estates in Mufindi District, Tanzania**

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A study was conducted in Mufindi district in Tanzania to determine the status of zinc and the response of tea to zinc application. Soil zinc status was assessed using a sequential extraction procedure and DTPA extractant. Leaf zinc status was assessed using a wet oxidation procedure. Five levels of zinc: 0, 2.5, 5.0, 7.5 and 10 kg Zn ha<sup>-1</sup> applied both on the foliage and on soil were used. Zinc fractionation indicated that of the total soil zinc, 4.2% was exchangeable, 1.1% associated with carbonates, 18.1% with organic matter, 23.5% with oxides and 49.9% with the residual fraction. Thus, the largest proportion of zinc was associated with the residual fraction. The DTPA extractable zinc ranged from 0.70-3.46 and from 0.70-5.20 mg kg<sup>-1</sup> in the cultivated and virgin soils, respectively. Leaf zinc concentration ranged from 11.76-32.64 mg kg<sup>-1</sup>, indicating that some estates were deficient in zinc. Foliar application of zinc at a rate of 2.5 kg Zn ha<sup>-1</sup> significantly ( $p < 0.05$ ) increased tea yields by up to 32%. Soil application of zinc decreased yields slightly, probably due to unfavourable interaction between zinc and other cations, especially magnesium. The critical zinc deficiency level was estimated to be 1.7 mg DTPA zinc kg<sup>-1</sup>. Soils with DTPA zinc of less than 1.7 mg kg<sup>-1</sup> are likely to respond to zinc application. More than 55% of the estates were deficient in zinc. Foliar application of zinc oxide at a rate of 2.5 kg Zn ha<sup>-1</sup> is recommended.

**Key words:** DTPA, extractant, organic matter, Zn fractionation

### **Minjingu phosphate rock as a source of phosphorus for grapevine in Dodoma District, Tanzania**

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Experiments were conducted to assess the P status of selected soils of Dodoma district, Tanzania and the response of grapevine to P application. The experimental sites were Msalato A, Msalato-Manispaa and Veyula-Makutupora. The studies included (i) an incubation study, and (ii) a field trial which compared MPR and TSP as sources of P. The soil fertility status decreased with increasing distance from the tree trunk congruent to the location of the fertiliser band. In the incubation experiment, solubility of MPR was increased steadily until equilibrium was reached at about 45 days. At this time, 52% of the applied MPR, equivalent to 260 mg P kg<sup>-1</sup> had dissolved. Soil samples incubated with TSP at this time released 64% of soluble P. Calcium and phosphorus sinks were demonstrated as important parameters that influenced P dissolution in the test soils. Both TSP and MPR application increased grape yield significantly

over the control, with TSP giving higher yield than MPR. The relative agronomic effectiveness value for MPR was 67%, suggesting that TSP had a higher fertiliser value than MPR. Phosphorus rates above 168 kg P ha<sup>-1</sup> decreased grape yields at Veyula-Makutupora site while at Msalato A and Msalato-Manispaa sites, yields continued to increase.

**Key words:** Calcium, phosphorus sinks, TSP

### **Potential and constraints of Kilombero Estate in Tanzania soils with respect to sugarcane production**

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A study was carried out in Kilombero Sugar Estate in Tanzania to determine the soil constraints that limit sugarcane production. The study revealed that the cultivated soils in Sections 1 to 3 were young (AC) profiles, very deep alluvial deposits. The virgin soils had relatively more advanced profile development (ABC profile) compared to the cultivated soils. Generally, soils were of mixed clay mineralogy with kaolinite, illite, smectite and goethite in varying proportions. Total nitrogen in all soils was low (0.08 to 0.15%). Poor soil aeration and drainage, and flooding effects limit sugarcane production in Sections 2 and 3. The cultivated soils of sections 1, 2, and 3 were classified as Eutric Fluvisol, Mollic Fluvisol (KLP1) and Mollic Gleysol (KLP3), Mollic Fluvisol (KLP1) and Mollic Gleysol (KLP2), respectively, according to FAO-UNESCO system of classification. The virgin soil (KLP4) was classified as Eutric Cambisol. According to USDA Soil taxonomy, the soils were classified as: Section 1, Typic Ustifluvent; Section 2, Typic Haplaquoll; Section 3, Fluventic Haplaquoll; and the virgin soil as Typic Tropaquept.

**Key words:** Kaolinite, illite, smectite, goethite, nitrogen, flooding

### **Microlysimeters for soil water evaporation measurement under shade and soil texture in Tanzania**

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The effect of soil texture and shade on soil water evaporation using microlysimeters of different sizes was investigated at Ismani, in Iringa region in Tanzania selected for its clayey soils, and (b) Hombolo, in Dodoma region which had sandy soils. Sandy soils evaporated significantly ( $p < 0.05$ ) more to about 20 percent, than clayey soils. Shading significantly ( $p < 0.05$ ) reduced evaporation by 5 to 10 percent. The 10 cm diameter microlysimeters lost more water than ones of the 5 cm diameter. This was more prominent in clayey soils than in the sandy soils, at the initiation of the experiment. However, towards the end of the study the difference was reduced.

**Key words:** Clayey, sandy, shading

### **Effect of *Gliricidia sepium* green manure placement on solubility of Minjingu rock phosphate, growth and yield of maize at Morogoro, Tanzania**

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This study was carried out at Sokoine University of Agriculture farm, Morogoro, in Tanzania to assess the effect of *Gliricidia sepium* green manure (GM) placement method on solubility of Minjingu rock phosphate (MRP), and growth and yield of maize. The study involved experimental factors; *G. Sepium*. (GM) placement method ( $5 \text{ t ha}^{-1}$ ) at three levels (i.e. No GM, Incorporation and Mulching) and P-fertiliser application rates at seven levels (i.e. 0, 12.5, 25, 50, 100, 150 mg P kg soil<sup>-1</sup> as MRP and 50 mg P as TSP). Green manure available P placement method significantly ( $p < 0.05$ ) improved (AVP), with the highest AVP obtained by the incorporation treatment. In most of the sampling dates, AVP values for incorporation and mulching treatments were not significantly ( $p > 0.05$ ) different. The AVP increased with increase in MRP application for all sampling dates. Except for stover N, GM placement method significantly increased the concentration and content of P and N in maize leaf. For the incorporation treatment, the values were leaf concentration (0.2005% P, 2.298% N) and leaf content (5.835 mg P, 66.19 mg N). The corresponding values for the mulching treatment were leaf concentration (0.1908% P, 2.252% N) and leaf content (5.426 mg P, 63.43 mg N). Similarly, P and N uptake were significantly increased by GM placement method. The uptake values for incorporation treatment were grain (6.22 kg ha<sup>-1</sup> P, 37.82 kg ha<sup>-1</sup> N), stover (2.18 kg ha<sup>-1</sup> P, 10.98 kg ha<sup>-1</sup> N). Whereas corresponding values for the mulching treatment were grain (5.40 kg ha<sup>-1</sup>; 33.77 kg ha<sup>-1</sup> N), and stover (1.76 kg ha<sup>-1</sup> P; 9.59 kg ha<sup>-1</sup> N). Total P and N and maize height as affected by GM placement method followed a pattern similar to that of P and N for grain and stover. Maize yield was 2.07 kg ha<sup>-1</sup> grain, 2.57 kg ha<sup>-1</sup> stover for control; (2.60 kg ha<sup>-1</sup> grain; 3.33 kg ha<sup>-1</sup> stover for incorporation; and 2.34 kg ha<sup>-1</sup> grain, 2.98 kg ha<sup>-1</sup> stover for mulching. Phosphorus and N uptake by maize significantly increased with increase MRP application. However, at higher rates (i.e. 40, 80 kg P ha<sup>-1</sup> as MRP), the increase of maize leaf P and P uptake was not significant. Generally, most of the parameters studied showed a linear and quadratic relationship with MRP application rates. Furthermore, the interactions between GM placement method and MRP application rates for most of the parameters studied were not significant.

**Key words:** Available P, nitrogen, stover, TSP

### **Soil phosphorus availability in Sao hill forest plantations in Iringa, Tanzania**

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A study was undertaken to investigate soil phosphorus availability in selected Sao Hill Forest Plantations located in Iringa region, Tanzania. Pine and Eucalyptus are the major species in Sao Hill forest project. Soil samples were collected from three adjacent stands of pine, eucalyptus and pine-eucalyptus mixture and analysed for physical and chemical properties. Composite top soil samples were collected from each stand at a depth of 0 to 20 cm and used for bioassay experiments in which three levels of n and four levels of P were factorially arranged. *Eucalyptus*

*saligna* seeds were directly sown into pots containing 1.8 kg of soil (oven dry weight basis). Soil exchange sites were dominated by aluminium (33%) and the soil was deficient in ( $p < 10 \text{ mg P kg}^{-1}$ ). The amount of P extracted by resin, Bray 1, Bray 2 and iron oxide filter strips were significantly ( $p < 0.05$ ) affected by P fertilisers. Iron oxide filter paper strips extracted the highest amount at any P rate followed by the resin method. Plant P uptake was significantly and highly correlated with Bray II P ( $r = 0.70$ ), Resin P ( $r = 0.64$ ), Bray I P ( $r = 0.63$ ) and iron oxide filter strips ( $r = 0.59$ ). In the untreated soils, absorption maximum was lower than the mixed stand, but this stand had the highest bonding energy. The potential buffering capacity was lowest in Eucalyptus stand. The absorption maximum was little affected by fertilisers while, as expected the bonding energy decreased with increasing fertiliser rate. Most of the added P was recovered as  $\text{NaHCO}_3\text{-P}$ . Most of the extraction methods correlated well with at least one of the soil fractions. Application of P fertilisers had a significant ( $p < 0.05$ ) effect on seedling height in the soils from all the stands. Root collar diameter, total and components dry matter of eucalyptus seedlings were significantly different ( $p < 0.05$ ) at different levels of P. Total and components P contents were significantly ( $p < 0.05$ ) affected by P fertilisation and also there was a significant interaction between soil source and P fertiliser. Soils from different stands significantly ( $p < 0.05$ ) affected foliar P concentration of *E. saligna* seedlings, indicating that the pine stand was P deficient. Application of N and P to *E. saligna* significantly increased N and P concentration and growth variables confirming P deficiency.

**Key words:** Bray I, Bray II, Eucalyptus, pine, resin

## **Soil and land evaluation of a section of Kilombero Valley in Tanzania**

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A section of Kilombero Sugar Company of about 400 hectares in Tanzania was soil surveyed and the land evaluated. Twenty one pits distributed over the different units were excavated and described for their external and internal features. The soils were classified using the Soil Taxonomy of the USDA, while the FAO frame-work was used for land evaluation. Inceptisols were the most dominant, while Entisols were prominent in areas within active river action. Ultisols occupied areas where the soils were formed *in situ* and Mollisols appear only in small patches. Six mapping units were identified; namely well drained Mlimani in the west and Mtoni in the south, the moderately well drained Msolwa and Msolwa-Bwawani complex in central areas and the imperfectly well drained Bwawani and Nyarubungu in very low lying eastern parts of the study area. Mlimani was highly suitable for sugarcane; some parts of Msolwa and Mtoni as moderately; suitable, while Msolwa-Bwawani, and Bwawani were marginally suitable for this crop. Nyarubungu was not suitable for growing sugarcane. Wetness limitation influenced parts of Msolwa, Bwawani and Nyarubungu, while soil fertility limitation influences msolwa-Bwawani, Msolwa and Nyarubungu. Soil physical limitation mainly due to texture has also been found to influence Mtoni section. Drainage, flood control, selection and application of fertiliser and irrigation recommended as some of the agricultural practices and measures for increased sugarcane production. Rice was suggested as an alternative crop for Nyarubungu where sugarcane growing was not suitable.

**Key words:** Entisols, FAO, mollisols, sugarcane, USDA

## Studies on phosphate sorption in Tanzanian Haplustox and Vitrandept soils

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Two virgin soils, a Haplustox with appreciable amounts of kaolinite, amorphous ferri-alumino silicate (AFAS), and oxides and hydrous oxides of iron,; and a Vitrandept dominant in AFAS with very little crystalline minerals, were chosen for this study. Phosphate sorption in these soils was investigated with respect to length of equilibration, initial solution concentration and pH, organic matter content, and amount and nature of extractants. It was also attempted to assess the equilibrium-P required for near maximum growth of maize (*Zea mays* L., var. Ilonga composite) and bean (*Phaseolus vulgaris* L. var Canadian wonder). With respect to the length of equilibration, rapid P sorption was observed initially in both the soils, but near equilibrium condition was obtained only after 24 hours. The magnitude of sorbed-P increased with increasing initial P concentration in the equilibrating solution. The initial solution pH had no effect on P sorption. Destruction of organic matter led to over three fold increase in P sorption in both the soils. The amount of desorbed P increased with increasing volumes of water, 1M KNO<sub>3</sub> or 1M K<sub>2</sub>SO<sub>4</sub> solution. The SO<sub>4</sub><sup>2-</sup> ion desorbed more P than the NO<sub>3</sub><sup>-</sup> or OH<sup>-</sup> ion. Studies in the greenhouse showed that dry matter yield, percent P in plant tissues and total P uptake for both the crops grown on either soil increased with increasing equilibrium-P up to certain concentration beyond which these parameters tended to reach a plateau. On the Haplustox soil, 95% of the maximum maize yield was obtained at an adjusted P concentration of 9.7 µg P ml<sup>-1</sup> while 2.6 µg P ml<sup>-1</sup> was adequate on the Vitrandept soil. For bean, 95% of the maximum yield was obtained at 9.5 and 5µg P ml<sup>-1</sup> adjusted P concentrations in the Vitrandept and Haplustox soils, respectively. From economic considerations, however, an adjusted P concentration lower than that required for 95 percent of the maximum yield is suggested.

**Key words:** Bean, Haplustox, iron, Kaolinite, maize, Vitrandept

## The status of phosphorus in some Tanzania soils

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A study was conducted on the fractionation of inorganic phosphorus from the main soil orders found in Tanzania. It was found that the extraction time of one hour for AL-P with NH<sub>4</sub>F solution offered the least dissolution of iron-bound and calcium-bound phosphates in the soil. Ammonium fluoride extracting solution of pH 8 was the most selective extractant for AL-P as it had the least attack on the Fe-P and Ca-P in the soils. Inorganic phosphate fractions were determined in 23 soil profiles from eight soil orders commonly occurring in Tanzania. The distribution percentages for Ca-P, A1-P and Fe-P were sensitive indicators of the weathering environment. In young soils, calcareous or the parent material rich in phosphorus bearing minerals Ca-P was the dominant fraction of inorganic phosphorus. In highly weathered, soils A1-P and Fe-P were the dominant fractions. The distribution of organic phosphorus was highest on the clay followed by silt separates. Clay and silt also contained the highest amount of A1-P and Fe-P, while the Ca-P fraction was highest on the sand. Organic phosphorus content decreased with depth, except in a few cases where the accumulation of organic phosphorus tended to occur in the second horizon. The C:P ratio of the organic matter in the

A horizons of the soil orders ranged from 25.7 to 493.3. The majority of the C:P ratios were below 200. The activity of the enzyme phosphomonoesterase as measured by the amount of phenol liberated in soils significantly correlated with altitude and organic phosphorus. A highly significant negative correlation was obtained between the enzyme activity and the C:P ratio. The enzyme activity decreased as the C:P ratio increased. The enzyme activity decreased as the C:P increased and would appear to tail off around a C:P value of 200.

**Key words:** C:P ratio, calcium, enzyme activity, iron oxides

### **Pollution and adsorption of mercury in Tanzanian soils and effect on plants and microbial activity**

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Studies were conducted to evaluate mercury (Hg) pollution of effluent, air, and soil near a battery factory in Dar es Salaam, to examine adsorption and mobility of Hg, its uptake by wheat and beans, and its effects on microorganisms in Morogoro, Arusha, and Dar es Salaam soils. Effects of sample pretreatment on Hg losses from plant materials were also studied to establish optimal conditions. Effluent, air and soil near the battery factory contained Hg levels of up to 5.2 mg L<sup>-1</sup>, 4.0 g cubic metre<sup>-1</sup>, and 472 mg kg<sup>-1</sup>, respectively. Soil Hg content decreased to 1.1 mg kg<sup>-1</sup> two km away in the direction of wind, indicating the influence of winds on Hg dispersal. The soils displayed large capacity to adsorb applied Hg, but varied in adsorption capacities. Mercury adsorption depended both on soil: solution ratio and on the initial Hg concentration in solution, indicating that results obtained using different ratios and concentrations should not be compared. Removal of organic matter from soil resulted in large reductions in Hg adsorption, as much as 95% from mercuric chloride and 31% from 2-methoxyethylmercury chloride (Aretan), suggesting that organic matter played a major role in the adsorption of inorganic Hg, while soils' mineral matter was involved more in the adsorption of the organic Hg compound. For all soils, adsorption of mercuric chloride increased with pH (pH 5 and 8). Adsorption of Aretan showed little or no change with this pH increase. In the Morogoro soil, Aretan adsorption was correlated well ( $r=0.821$ ) with the natural horizon wise variation in pH. Similar correlations were obtained with organic matter and CEC distribution for both Hg compounds. No such correlations were observed with the Arusha and Dar es Salaam soils. All soils showed greater capacity for Aretan than for mercuric chloride adsorption, but the bonding energy was larger for the latter. The Freundlich isotherm described the adsorption of mercuric chloride better than that of Aretan. There was little mobility of Hg from mercuric chloride when leached with water or dilute salt solution, and it moved to only 8 cm depth even when leached with 0.5 M calcium chloride or 0.1 M EDTA. Crop plants generally absorbed very little Hg from soil (up to 5 mg Hg kg<sup>-1</sup> soil), although the absorption increased with soil Hg levels. A 50 mg Hg kg<sup>-1</sup> soil, wheat straw and grain absorbed 261 and 236 µg Hg kg<sup>-1</sup>, respectively, from mercuric chloride, but much less from Aretan. Bean straw from 5 mg Hg kg<sup>-1</sup> soil contained 45 and 23 µg Hg kg<sup>-1</sup> from mercuric chloride and Aretan, respectively, but only 1 µg kg<sup>-1</sup> was translocated to grain from both compounds.

**Key words:** Bonding energy, Dar es Saalam, organic matter, sorption

## **Evaluation and classification of soils developed over gneiss, limestone and marine sediments in Mlingano in Tanzania**

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This study, covering 5,876 square kilometers was conducted to perform detailed characterisation, genesis, classification of the soils and land suitability assessment for sisal, citrus, maize and groundnuts in Tanzania. The soils were deep, free draining, with red to dark reddish brown hues. Textures ranging from loamy sands to sandy clays, were related to the content of the weatherable minerals initially present. Finest texture was observed on the gneiss and coarsest on the marine deposits of higher coastal plain. Ages and initial weatherable minerals were limiting on the higher coastal plain, and on the lower coastal plain. Colour was strongly related to the iron bearing minerals initially present in the parent material. The highest content of these minerals was in the gneiss and the lowest in the material of sandy nature on the higher coastal plain. All the soils were strongly weathered judged by the silt/clay ratios. The parent material could have been preweathered on the higher and lower coastal plain. Within the study area, weathering becomes relatively stronger from the marine sediments to the gneiss, judged by the activity of the clay fraction. Most of the soils were strongly leached with pH < 4.8 at least in the subsurface horizons. This was the case in the soils of higher slopes on the gneiss, on the limestone, on the higher coastal plain and soils on the upper slopes of lower coastal plain. Leaching was related mainly to slope rather than parent materials. The soils fitted in the fine clayey kaolinitic isohyperthermic family of Typic Haplustox on the upper slopes of gneiss, Fine clayey kaolinitic isohyperthermic family of Oxic Paleustalf on the lower concave slopes of gneiss. Fine clayey mixed isohyperthermic families of Typic Haplustult and Paleustult occurred on the upper slopes of the limestone and Fine loamy mixed isohyperthermic family of Paleustult on the lower slopes of limestone. Fine and coarse loamy mixed isohyperthermic families of Typic Ustorthent were on the upper slopes of the higher coastal plain and sandy siliceous isohyperthermic family of Typic Ustipsamment on the lower slopes of the higher coastal plain. Fine clayey mixed isohyperthermic family of Typic Ustifluvent were on the higher slopes of lower coastal plain, and fine loamy mixed isohyperthermic family of Typic Ustifluent on the lower slopes of the lower coastal plain. According to the FAO/ UNESCO Soil Map of the World Legend the soils fitted into Orthic and Rhodic Ferralsol on the upper slopes on the gneiss, Eutric Nitosol on the lower slopes of the gneiss, Orthic Acrisol and Dystric Nitosol on the upper and lower slopes of limestone, respectively, Cambic and Albic Arenosol on the higher coastal plain and Eutric Fluvisol on the lower coastal plain. Rainfall, evapotranspiration and soil characteristics were used to identify six land units in the study area. Maize and groundnuts were marginally suitable in all the land units; sisal marginally unsuitable in three and suitable in three land units; citrus marginally unsuitable in three, highly unsuitable in two and marginally suitable in one unit. Moisture availability was the most limiting land quality; it was limiting in four land units for sisal and five units for citrus. The second most limiting land quality was nutrient availability; which was moderately limiting for the 4 crops in all the six land units. Other important limitation was susceptibility to erosion for sisal, citrus, maize and groundnuts in two units.

**Key words:** Citrus, groundnuts, maize, sisal, Typic Haplustox

### **Major forms of soil erosion in morning side catchment, Uluguru Mountains in Tanzania**

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Soil erosion is prevalent in the tropical mountainous zones leading to both environmental hazards and low incomes. Efforts to arrest soil erosion have progressed very slowly due to lack of adequate data and link between specific soil erosion processes and the corresponding control measures. This study focused on the identification of the major forms of soil erosion, spatial distribution of their severity and the factors responsible for their occurrence. The aim was to develop a database for soil conservation in the Morningside catchment of uluguru mountains. Geopedologic survey techniques were employed to characterise and map the geomorphic setting and soils of the Morningside catchment covering an area of about 15 km<sup>2</sup>. These were coupled with detailed study on the major forms of soil erosion and measurements of soil loss. ILWIS software was used to determine the spatial distribution of the various forms of soil erosion. The dominant soil erosion processes which varied with the geomorphology included interrill, rill, tillage erosion and landslide. Interrill erosion dominated on areas with slope gradient < 50%. Rill erosion affects nearly 60% of the studies area and was significantly higher ( $p < 0.001$ ) in most geopedologic units with slope gradient > 50%. In these units, the mean soil loss ranged from 91 to 258 t ha<sup>-1</sup> year<sup>-1</sup>. A significant correlation existed between the rate of both interrill and rill erosion with slope gradient and certain soil properties. About 81% of the variations in soil loss due to interrill erosion could be accounted for by slope gradient, bulk density, silt/clay ratio and content of rock fragments, while 97% of the variations in soil loss due to rill erosion could be explained by slope gradient, contents of water stable aggregates and soil texture. Landslides dominate in the mountain ridges where they affected 20% of the land. The most conducive factors for the occurrence of landslides were slope gradient, roads and pathways, irrigation channels, steep concave slopes and the presence of shallow and porous soil overlying relatively less porous substratum. Soil flux rates due to tillage increased with slope gradient from (43 - 70 kg m<sup>-1</sup> tillage pass<sup>-1</sup>) on slopes of 0.31 - 0.67 m m<sup>-1</sup>, with mean transport coefficient of 107.5 kg m<sup>-1</sup>. Deep tillage favoured the magnitude tillage erosion, but it was considerably reduced by surface residues.

**Key words:** Geopedologic, ILWIS, land slides, rill, tillage

### **Minjingu phosphate rock with organic inputs for improving phosphorus availability on a Chromic Acrisol in Tanzania**

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Phosphorous deficiency in highly weathered soils is one of the causes of low crop yields in Tanzania. Use of Minjingu phosphate rock (MPR) in combination with organic inputs is considered to be a possible option for increasing P availability and crop yields. However, detailed characterisation of organic inputs, their effects when used alone or combined with MPR on soil characteristics, and maize yields are limited. This study was conducted to evaluate farmyard manure (FMY), tithonia, lantana and glicidia combined with MPR on soil properties, P availability and maize yield on a Chromic Acrisol. Manure and tithonia had more P than the

critical value for net P mineralisation. Tithonia contained the highest amounts of light molecular weight organic acids, oxalic acid being the most dominant. All organic materials depressed MPR dissolution and the depressing effect increased with increased in pH, Ca and P content of the materials. Organic materials at 2.27 g kg<sup>-1</sup> (5 t ha<sup>-1</sup>) increased soil pH, exchangeable Ca and decreased exchangeable Al. All organic materials increased labile P pools and reduced P adsorption maximum and P affinity. This resulted in increase in available P and in maize dry matter yields. Under field conditions tithonia increased soil pH, exchangeable Ca and oxalic acid concentration and decreased exchangeable Al. Tithonia decreased P sorption and increased total P, and maize yield. The decrease in P adsorption increased with tithonia rates, with the rate of 7.5 t ha<sup>-1</sup> resulting in the largest agronomic optimum. MPR was superior to TSP (80 kg P ha<sup>-1</sup>) in increasing pH, Ca, oxalic acid and in reducing exchangeable Al. Both sole MPR and sole TSP reduced P adsorption but the influence of MPR was greater than that of TSP. MPR was superior to TSP in supplying Ca, oxalic acid and in increasing pH in all seasons. Combining MPR with tithonia had a higher RAE in two out of the three seasons than that under sole tithonia or MPR. Organic materials alone or combined with MPR improved soil pH, Ca and decreased exchangeable Al.

**Key words:** Farm yard manure, Labile P, maize, Tithonia, TSP

### **Influence of Minjingu phosphate rock application on *Tephrosia vogelii* fallow productivity and subsequent maize response on a ferralsol**

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This study was conducted to quantify the response of *Tephrosia vogelii* fallow to Minjingu Phosphate Rock (MPR) application at establishment in terms of quantity and quality of biomass produced, P availability, total inorganic-N, maize yields, and pH and Ca changes on Ferralsol in Tanzania. For soil of pH 5.9, the quantity, quality and N<sub>2</sub> fixing capacity of *T. vogelii* seedlings were significantly (p<0.05) improved relative to pH 5. Combined application of *T. vogelii* biomass and MPR significantly increased maize DM yield but depressed Pi-P in the incubation study. Decomposition of *T. vogelii* biomass was significantly increased only in the first 28 days by MPR application. Minjingu PR application at fallow establishment significantly increased the quantity and quality of *T. vogelii* biomass, total inorganic-N and Pi-P in the fallows. Subsequent to fallows, application of *T. vogelii* fallow biomass or combined with MPR significantly increased total inorganic-N. The Pi-P, earleaf N and P concentrations, soil pH, exchangeable Ca and maize yields were significantly increased by application of MPR at fallow establishment and by combined MPR with fallow biomass.

**Key words:** Calcium, inorganic N, nitrogen fixation, Pi-P

### **Influence of cover crops on soil nitrogen and moisture content and maize yield Tanzania**

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A study was conducted in Morogoro, Tanzania to evaluate the influence of cover crops on N availability, soil moisture and grain yield of the subsequent maize crop. The cover crops included cowpea (*Virgna unguiculata* (L) Walp.), lablab (*Lablab purpureus*), mucuna (*Mucuna pruriens*) and pumpkin (*Cucurbita maxima*). The cover crops were evaluated against weed and bare fallows. Cover crop produced >30% ground cover, after 60 DAP in years with good short rains. Ground cover was in the order weed fallow = macuna > cowpea > pumpkin > lablab. Biomass was higher for mucuna and lablab, (2.7 – 5.1 and 1.6 – 3.9 t ha<sup>-1</sup>, respectively) with good short rains and < 1.5 t ha<sup>-1</sup> with inadequate short rains. Nitrogen content in pumpkin and lablab residues was more affected by drought than in mucuna and cowpea. Cover crop residues contained 15 to 118 kg N ha<sup>-1</sup>. Nitrogen flush after cowpea lablab and mucuna was higher than after pumpkin, weed and bare fallows. Moisture content in the topsoil under cover crops and weed fallow were similar, but were higher than in bare fallow. In the long rains, soil moisture content in the subsoil was higher after mucuna, lablab an weed fallow plot than after pumpkin, cowpea and bare fallow, lower following mucuna, lablab and weed fallow than following cowpea, pumpkin and bare fallow. Maize grain yield was higher after mucuna and l lablab than in other treatments. Mucuna and lablab were better than other cover crops in terms of biomass production, reduction of runoff, moisture conservation, N supply and maize grain yield.

**Key words:** Cowpea, Lablab, mucuna, nitrogen flush, pumpkin

### **Contribution of grain legumes to nitrogen requirement of maize under intercropping and rotation on a Ferralsol in Tanzania**

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A study was carried out to determine the contribution of cowpea, pigeonpea and greengram to the N requirements of maize grown as intercrops or in rotation on a Ferralsol in Tanzania. Cowpea, pigeonpea and greengram fixed N<sub>2</sub> to meet 45, 37 and 20% of their N requirements, respectively. Three legumes in the order above fixed 37, 19 and 38%, under intercropping and 40, 25 and 39%, under rotation of their N requirements with maize, respectively. The decomposition of the legume residues and native soil organic matter in both cropping systems improved the mineral N (NH<sub>4</sub><sup>+</sup> plus NO<sub>3</sub><sup>-</sup>) supplying potential of the soil at maize planting time. Most of the mineral nitrogen was released during the two weeks following maize planting. Much of the mineral N was in the NO<sub>3</sub><sup>-</sup> form, which decreased with increasing depth. At maize tasselling, the mineral N contents in the 10 - 30 cm soil depth were lower than the contents 0-10 or 30-45 cm depths due to this. Cowpea, pigeonpea and greengram above-ground residues contributed 6, 8, 2.9 and 4.0 kg N ha<sup>-1</sup> under intercropping, respectively, derived from N<sub>2</sub> fixation when intercropped, and 14.0, 6.6 and 7.4 kg N ha<sup>-1</sup> under rotation. The effects of the pegeonpea intercropping on subsequent maize yield were equivalent to 28 and 34 kg N ha<sup>-1</sup> when maize stover was removed and left on the plots, respectively. The effect of the cowpea, pigeonpea and greengram rotation on maize grain yields were equivalent to 20, 25 and 14 kg N

ha<sup>-1</sup> when the maize stover was removed, and 21, 38 and 22 kg N ha<sup>-1</sup>, when the maize stover was left on the plots. The N contributed by the legumes under intercropping or rotation with maize was insufficient, and should be supplemented with mineral N fertiliser for optimum maize yields.

**Key words:** Cowpea, greengram, nitrogen fixation, pigeon pea

### **Pesticide effects on bean and *Sesbania* rhizobia and their symbiotic relationship**

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Laboratory and glasshouse experiments were conducted at the Sokoine University of Agriculture, Morogoro in Tanzania to evaluate the effect of kocide 101 (77% cupric hydroxide) a fungicide and oxadiazon [3-(2,4-dichloro-5-(1-methylethoxyphenyl)-5-(1,1-dimethylethyl,3,4-oxadiazol-2(3H)-one)] a herbicide, on growth and symbiotic performance of bean (*Phaseolus vulgaris* L.) and *Sesbania rostrata* rhizobia, respectively. Kocide 101, in the broth medium inhibited growth of rhizobia. Of the three strains tested for sensitivity of kocide 101, *Sesbania* isolate was most tolerant followed by the PV<sub>1</sub> strain, and lastly, by strain CIAT 899. The growth of *Sesbania* rhizobia in broth media was unaffected by the addition of oxadiazon. The application of kocide 101 at the recommended application rate (equivalent to 1.7 mg kg<sup>-1</sup> soil) had no harmful effect on growth, nodulation and nitrogen fixation. Kocide 101 applied at 2x and 4x the recommended application rate equivalent to 3.4 and 6.8 mg kg<sup>-1</sup> soil was detrimental. The inhibition of nodulation and N<sub>2</sub> fixation in the presence of kocide 101 was mainly due to the direct effect of the fungicide on the bean plants. Application of oxadiazon at the recommended application rate, at 2x and at 4x the recommended application rate (equivalent to 0.75, 1.50, and 3 mg kg<sup>-1</sup> soil, respectively) adversely affected the growth, nodulation and N<sub>2</sub> fixation by *Sesbania rostrata* plants. The inhibition in nodulation and N<sub>2</sub> fixation in the presence of oxadiazon was, to a large extent, due to adverse effects of the herbicide on plant growth and development rather than on rhizobial viability.

**Key words:** Methylethoxyphenyl, *Phaseolus vulgaris*, *Sesbania rostrata*

### **Pedological and mineralogical investigation of soils developed of different parent materials/rocks in coast region of Tanzania**

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A pedological and mineralogical study was undertaken in Coast Region, Tanzania, to investigate soil developed on four different parent materials/rocks, namely (a) migmatitic biotite gneiss of Precambrian age, (b) calcareous siltstone and sandstone of Jurassic age, (c) grey green marls of Cretaceous age, and (d) sands and gravels of neogene age. The objective was to carry out inventory of the ecological conditions, to characterise, and classify soils. The soils were red, very deep, well drained, friable and clayey. Soil pH ranged from slightly acid to moderately acid (pH 5.5 – 6.3). The CEC ranged from 24-26 cmol kg<sup>-1</sup>. Base saturation ranged from 25-48%. The

clay fraction was dominated by kaolinite of pedogenic origin. Soils were classified as Haplic Alisol (FAO, 1988) or Typic Rhodustult (Soil Survey Staff, 1990). Profile CRP2 represents soils developed from calcareous siltstone and sandstone. These soils were brown, shallow to moderately deep, well drained, friable and clayey to gravelly clayey. pH increased with depth from very slightly acid to moderately alkaline (pH 6.5-8.1). The CEC was high (30-36 cmol kg<sup>-1</sup>). Base saturation ranged from 53-73%. The clay fraction was characterised by mixed mineralogy including smectite, vermiculite, mica and traces of kaolinite. The soils were classified as Eutric Cambisol, lithic phase (FAO, 1988) or Lithic Ustropept (Soil Survey Staff, 1990). Profile CRP3 represented soils developed from grey-green marls. The soils were black, very deep, moderately well drained, firm and clayey. They had pronounced cracking (vertic) properties. Soil pH increased with depth from very slightly acid to moderately alkaline (pH 6.8 - 8.0). The CEC was very high ranging from 53 to 68 cmol kg<sup>-1</sup>. Base saturation ranged from 63-93%. The clay fraction was dominated by smectite. The Soils were classified as Calcic Vertisol (FAO, 1988) or Typic Pellustert (Soil Survey Staff, 1990). Profile CRP4 represented soils developed from unconsolidated sands and gravels. The soils were brown, very deep, imperfectly drained, friable, and had loamy sandy to gravelly sandy clay loam texture. The pH increased with depth from slightly acid to moderately alkaline (5.5 - 8.1). The CEC increased with depth from low to medium (9.2 - 2.8 cmol kg<sup>-1</sup>). Base saturation ranged from 21-73%. The clay fraction was characterised by mixed clay mineralogy including; smectite, kaolinite, quartz and traces of gibbsite, Soils were classified as Dystric Planosol, duripan phase (FAO, 1988) or Aeric Tropaquept (Soil Survey Staff, 1990).

**Key words:** Calcic Vertisol, Cambisols, Eutrica, Haplic Alisol

### **Response of maize to Minjingu phosphate rock and farm yard manure on an Oxic Haplustult in Tanzania**

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A pot experiment was carried out to investigate the response of maize (*Zea mays* L) to various combination of Mingingu Phosphate Rock (MPR) together with Farm yard manure (FYM) applied to an Oxic Haplustult. The rates of FYM were 0, 7.5, 15 and 30 g kg<sup>-1</sup> and MPR were 0, 50, 100, and 150 mg P kg<sup>-1</sup> soil. The MPR-manure combinations were incubated for one month before sowing the maize seeds. Results showed an increase in Bray-1- extractable P by 8.3 mg P kg<sup>-1</sup> soil and P uptake by 0.13%. The above increases were attributed to the P released from solubilisation of MPR and decomposition and mineralisation of the farm yard manure. The small increases in Bray I extractable phosphate increased with time of contact between soil – MPR and FYM. Response by crops to phosphate released from MPR-FYM-combinations would be more pronounced when applied to the soil 6 to 12 months before planting, to ensure optimal solubilisation and decomposition of the MPR and FYM, respectively.

**Key words:** Bray 1, decomposition, mineralisation, solubilisation

## Soil fertility status of paddy growing areas of Tanzania

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Nitrogen, phosphorus, zinc and iron deficiency or limited availability is the main soil fertility constraint limiting rice (*Oryza sativa* L.) yields worldwide. The objective of this study was to develop diagnostic criteria for assessing the fertility status of the selected rice growing areas of Tanzania in terms of availability of the above nutrients. Soil samples were collected from 10 different areas where rice is grown, for laboratory analyses for the screening of suitable indices for available N, P, Zn and Fe in soils. All the soils used in this study were deficient in N, while 60% of the soils responded to P application. All the soils had adequate levels of K and Zn, although some of them appeared to be borderline cases between adequate and deficient. Extractable Fe content was very high in all soils. Of the nutrient availability indices tested, OC correlated significantly with the DM yield, while Olsen extractable P was found suitable for P assessment with a critical level of 20 mg kg<sup>-1</sup> soil. None of the indices tested was suitable for Zn and Fe assessment.

**Key words:** Nitrogen, phosphorus, zinc, Fe, *Oryza sativa*

## Heavy metal accumulation in soils of vegetable growing areas of Mbeya District in Tanzania

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This study aimed at assessing the extent of contamination of soils by copper, zinc, and manganese in the vegetable fields of Mbeya district in Tanzania due to fungicide use. The effect of length of time of fungicide use on metal accumulation was evaluated. The influence of soil properties on the distribution of these metals in the soils were assessed. Five categories of length of time of fungicide use were assumed: 0 (virgin sites); 1-2; 3-5 6-10 and 11-23+ years. Sampling was done at various locations in the district based on these categories. It was found that Cu fungicides were more widely used than Zn or Mn fungicides. High levels of Zn and Mn in some sites were associated with natural occurrences rather than contamination from fungicides. In all sites and depths, Cu content was lowest in the virgin sites and increased with time of fungicide use. At 0-5 cm, mean Cu levels were 1.44 mg kg<sup>-1</sup> (DTPA-Cu) and 18.5 mg kg<sup>-1</sup> (Aquaregia-Cu) for the virgin sites, and 47.8 mg kg<sup>-1</sup> (DTPA-Cu) and 212.3 mg kg<sup>-1</sup> (Aquaregia-Cu) for the 11 –23+ years category.

**Key words:** Copper, DTPA, fungicide, manganese, zinc

### **Effect of selected insecticides on microbial numbers, *Leucaena* decomposition and biological nitrogen fixation**

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The effect of insecticides (Lannate and Karate) on the decomposition of *Leucaena* green manure and nitrogen fixation by cowpea were evaluated, after establishing their inhibitory effects on the decomposer microorganisms and their toxic effects on the bradyrhizobia *in vitro*. In the decomposition experiment manure in perforated plastic litter bags was buried (10 cm) in the soil contained in wooden troughs. Then insecticides were applied on the soil at final concentrations of 0.5 and 1.5 ppm for Lannate or 0.5 and 1.0 ppm for Karate. The effects of these insecticides each at 0.5 and 1.5 ppm on the cowpea –*Bradyrhizobium* symbiotic relationship were assessed in potted soil. Cowpea was grown and harvested after 35 days. Lannate and Karate had an apparent depressive effect on the growth of the heterotrophs at the 0.5 ppm concentration, but not at higher concentrations. The bradyrhizobial proliferation *in vitro* was more affected by Lannate than Karate. However, nodulation and nitrogen fixation was not significantly affected by any of the insecticides at any of the concentrations tested.

**Key words:** Cowpea, Karate, Lannate, nodulation, rhizobia

### **Effect of seed-bed conditions, planting rain and seed vigour on establishment of maize**

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A study was conducted to evaluate the effect of seedbed condition, planting rain and seed vigour on maize seedling establishment in Tanzania. Two main plots, each with 5 subplots, were laid out. Water equivalent to 50 mm rain was applied uniformly to each of the two main plots on the same day. A day after application of the 50 mm, ploughing was undertaken sequentially, a subplot every day, for 5 days resulting in 5 seedbed conditions (SBC) giving treatments SBC 1-5. High and low vigour maize seeds were planted. Planting rain equivalent to 15 mm was applied to one of the two main plots.  $l_k$  density ( $j_p$ ) was significantly ( $p < 0.05$ ) higher than in the virgin land only in the 40 mm planting rain treatments. Aggregate sizes of  $\leq 0.6$ , 2, 4, 6.3, 11, 20 and  $> 20$  mm diameter were categorised. Aggregates  $\leq 6.3$  mm diameter were 72 and 63% (in low and high planting rain treatments, respectively) in SBC 3 and were higher than in other SBCs. PR at 4 mm depth was the lowest ( $\leq 1$  MPa) in SBC 3, in both main plots. Overall emergence was low for low vigour seeds. Best emergence was observed in SBC 3, which had lowest PR and high percentage of aggregates  $\leq 6.3$  mm diameter in both planting rain treatments. Poor emergence was observed in SBC 1 and 5 in 15 mm planting rain plots and in SBC 1,2 and 5 in 40 mm planting rain plots. Seed beds with poor emergence had high PR values ( $> 2$  Mpa) and high percentage of large aggregates ( $> 6.3$  mm diameter). Significant ( $p < 0.05$ ) differences in shoot height and in number of leaves per plant were only observed with vigour categories were compared. The interaction between seedbed, planting rain and seed vigour had no significant effect on establishment of maize.

**Key words:** Aggregates, emergence, virgin land

## **Distribution and characteristics of Calcretes and Calcrete-soil profiles on the northern lower slopes of Uluguru Mountains Tanzania**

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This study was conducted in the area extending northwards from the footslopes of Uluguru mountains towards the Ngerengere river in Morogoro district in Tanzania. Kihonda transect was selected for detailed characterisation of different calcrete forms and the associated soils and regolith so as to understand the origin of calcretes, their characteristics and their influence on soil properties. Near Ngerengere river, the calcrete layer is considerably thinner (27.5 cm) than those on the lower slope (76 cm), midslope (135 cm), crest (106 cm) and neighbouring depression (142 cm) implying the influence of Ngerengere river on calcrete formation. Less developed calcretes occur near the river, while the most developed calcretes occur at or near the crest. Nodular, honeycomb and massive calcretes are the major forms of calcretes occurring on the transect. Their proportions along the transect, which reflect their lateral extension follows the order: nodular (94.9%), honeycomb (87.2%) and massive (51.3%). A considerable difference in purity exists among different calcrete forms ranging from 47.6% in nodular calcrete, 75.0% in honeycomb and 97.5% in massive form. This difference in purity is explained in terms of their difference in degree of development. A sharp difference in average  $\text{CaCO}_3$  content ranging from 7.7% in soil solum to 65.0% in calcrete layer exists. The latter implies a lithological discontinuity at the soil-calcrete interface. The difference is gradual from 65.0 to 37.7% at the calcrete-regolith interface. The source of the  $\text{CaCO}_3$  in the calcretes, is therefore, the underlying parent material. The calcretes are mainly constituted of micritic calcite. Sparite occurs on top of massive calcrete, in fissures, voids and around the relic minerals implying a multi-phase precipitation of calcite. Minor minerals are quartz, opaline silica and feldspars.

**Key words:**  $\text{CaCO}_3$ , honey-comb, massive, nodular, quartz

## **Pedological characterisation in Litembo Village in Tanzania**

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A pedological investigation was carried out in Litembo village, Mbinga district in Tanzania to identify the various soil types in terms of physical, chemical and mineralogical properties. It is clear that Litembo village has four major landforms i.e. plateaux, hills, piedmonts and valleys. Most piedmont soils are deep to very deep, having dark brown to dark reddish brown sandy clay topsoils and dark red to red clayey subsoils. The hills and plateaux have shallow sandy clay loam soils. All the soils are well drained to excessively well drained except those of the valley bottoms, which are poorly-drained. Top soil bulk densities range from 0.99 to 1.2  $\text{mg m}^{-3}$ , whereas subsoil values are slightly higher. Total porosity ranges from 56 to 72% in the topsoils and 40 to 53% in the subsoils. Topsoils have lower penetrometer resistance (PR values 0.1 to 0.28 MPa) than subsoil (PR values 3.97 –5.52 MPa). Available water capacity (AWC) of most topsoils ranges from 15 to 25% by volume and decrease slightly with depth. AWC per meter range from 125 to 177 mm which is medium to high. Soil reaction is very strongly acid to strong acid with pH values between 4.4 and 5.4 in topsoils and 4.4 and 6.0 in subsoils. Total nitrogen ranges from very low to medium (<0.03-0.3); phosphorus, exchangeable

bases, CEC and base saturation, range from low to very high in topsoils and very low in subsoils. The clay mineralogy is dominantly kaolinitic with accessory amounts of gibbsite and goethite. The piedmont soils classified as Ferric Acrisols, soils of the as Dystric Leptosols and Haplic Acrisols and valley bottom soils as Umbric Fluvisols. Litembo soils developed under intensive leaching environment, facilitated by a mountainous/hilly topography. Fertility status is poor, and due to steep slopes and weak soil structure, Litembo soils are prone to erosion.

**Key words:** Bulk density, Ferric Acrisols, Gibbsite, Kaolinite

### **Phosphorus release from Minjingu and Panda phosphate rocks in soils of Mbozi and Morogoro districts in Tanzania**

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Studies were conducted to assess the dissolution of Minjingu and Panda phosphate rocks and their partially acidulated products, in some soils of Mbozi and Morogoro districts, Tanzania. The experimental soils were Magadu, Ihanda and Sasanda which are classified as Oxic Haplustult, Oxic Haplustalf and Oxic Dystropept, respectively. Partial acidulation increased water soluble P fractions of the PRs. An increase of more than 40-fold was realised in PPR2. Presence of high oxides of iron and aluminium decreased the quality of PAPR in terms of available P. Partial acidulation increased the amount of NaOH-extractable P. The dissolution of the P sources varied among soils. After 56 days of incubation the dissolution of the PPR2 ranged from 6.4 to 42.5%; while the dissolution of its PAPR product ranged from 16.4 to 52.5% in the three soils. The amount of Bray 1-extractable P extracted from soils treated with the different P sources decreased with time mainly due to high P fixation capacity. Partial acidulation substantially increased the relative agronomic effectiveness (RAE) of this product. Whereas the mean RAE for the PPR2 in the three soils was 21.5% that of PAPR2 was 70%.

**Key words:** Agronomic effectiveness, oxic, partial acidulation

### **Pedological characterisation in Kitanda Village, Mbinga District, Tanzania**

Wickama, W.J.M.

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A pedological investigation was carried out in Kitanda village, Mbinga district in Tanzania to characterise the soils in terms of physical, chemical and mineralogical composition. Soil profiles representative of six mapping units covering an area of 5563 hectares were studied. Most of the soils are red to dusky red, well drained, clayey, friable, slightly sticky to sticky and plastic. Soils of the river valleys are brown to dark grey, poorly drained, sandy clay loam to clay, slightly sticky and plastic. Soil pH ranges from slightly acid (6.1) to strongly acid (4.8). Organic carbon ranges from very low (0.1%) to very high (5.5%). Cation exchange capacity (CEC) ranges from low (6 cmol kg<sup>-1</sup>) to medium (24 cmol kg<sup>-1</sup>). Base saturation ranges from 28 to 67%. Soil clay fractions are dominated by kaolinite and oxides of aluminium and iron. Most soil properties correlate well with landform. Pedogenically, the soils are old, highly weathered and have a high potential for fixation of phosphorus. Soil micronutrient levels are optimal except

for Zn in the moderately dissected piedmonts. Soils classify as Umbric Leptosols, Dystric Leptosols, Ferric Acrisols, Ferric Lixisols, Rhodic Ferralsols and Dystric Fluvisols respectively for hill summits (H1), hill shoulder (H2), strongly dissected slope facet complex (H3), strongly dissected piedmonts (P1), moderately dissected piedmonts (P2) and river valleys (V).

**Key words:** Aluminium, base saturation, CEC, Fe, Kaolinite

### **Effect of seed factors and seed-stay in soil on establishment of maize and sorghum**

Tarimo, B.O.

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A study was undertaken to assess the seed quality under commercial and condition on the establishment of maize (*Zea mays* (L)) and sorghum (*Sorghum bicolor* (L)). Seed of three cultivars of maize (Staha, TMV-1, and Kito) and one sorghum cultivar (Tegemeo) were obtained from Tanzania Seed Company (TANSEED) and farmers' seed. The study on the effect of length of time seeds remain in soil before the onset of rains, on establishment was conducted using high, medium and low vigour seeds. High vigour seeds were the fresh/unaged seed samples from the seed lots. Medium and low vigour seeds were obtained by artificial ageing of fresh seed for 2 and 3 days, respectively. Seeds from TANSEED had initial germination percentage ranging from 93 to 100%, (maize) and 92 to 96% (sorghum). Seeds from farmers had germination percentage varying from 64 to 99% (maize) and 8 to 65% (sorghum). Overall, sorghum seeds from TANSEED had relatively high germination capacity than those from farmers. Seeds from farmers had high initial seed moisture content (SMC) than commercial seed. Sorghum had higher SMC than maize irrespective of the source. Initial SMC was about 10 and 11% for maize and sorghum, respectively. Time to 50% germination ( $T_{50}$ ) increased with storage time for seeds obtained from TANSEED.  $T_{50}$  values (in days) for maize cv Staha lot were 2.2, (initially), 2.4 (after one month) and 2.7 after two months). Seeds from farmers showed no consistent trend. In both field and glasshouse studies, sorghum seeds emerged earlier than maize seeds.

**Key words:** Ageing, *Sorghum bicolor*, vigour, *Zea mays*

### **Effect of pit size in Ngoro cultivation system on soil water conservation and yield of maize in Tanzania**

Malley, Z.J.U.

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A field experiment was conducted at Lipumba village in the Matengo highlands of Mbinga District in Tanzania to evaluate the effects of three pit sizes (in *Ngoro* cultivation system) on runoff storage capacity, soil water conservation, maize (*Zea mays* L.) yield, and labour requirements. Three pit size systems, namely, 1.0 m x 1.0 m ( $T_1$ ), 1.5 m x 1.5 m ( $T_2$ ) and 2.0 m x 2.0 m ( $T_3$ ) were established on 15% and 55 slopes. The average runoff storage capacity as indicated by pit roughness indices (PRIs) ranged from 108 cm in  $T_1$  to 138 cm in  $T_3$ . In the *Ngoro* junctions,  $T_1$  had significantly ( $p < 0.01$ ) higher moisture (11.21 mm) than  $T_2$ . In *Ngoro* ridges,

high concentrations of organic matter (OM) ranging from 3.97-4.59%, and low bulk density (Db) ranging from 1.00-1.09 t m<sup>-3</sup> were found in the 5 to 15 cm soil layer. Increasing the pit size reduced labour requirement for their construction from 30.48 in T<sub>1</sub> to 20.46 man days in T<sub>3</sub>. However, this was significant (p<0.05) on the 55% slope sites only. Plant height was significantly (p<0.05) lower in T<sub>1</sub>. The profitability of T<sub>3</sub> was approximately 2 and 5 times that of T<sub>2</sub> and T<sub>1</sub>, respectively. Effect of pit sizes on soil water conservation was inconsistent. However, large pits (T<sub>3</sub>) had higher storage capacity, gave the highest plant height and grain yield, lowest penetrometer resistance and labour requirement and the highest profitability.

**Key words:** Labour, profitability, slope, *Zea mays*

### **Effect of fungicide use on coffee and vegetables on copper and other heavy metals in soils of Lushoto District, Tanzania**

Baruti, J.H.M.

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This study was conducted to quantifying the accumulation of Cu and other heavy metals in coffee and vegetable growing soils of Lushoto district, Tanzania. In vegetable fields, DTPA-extractable Cu and Zn in the top (0-5 cm) soil increased from of 4.3 and 9.8 mg kg<sup>-1</sup> respectively, in farms that never sprayed fungicide, to 52 and 12 mg kg<sup>-1</sup> in farms which received fungicides for more than 20 years. Total Cu and Zn increased from 44 and 63 mg kg<sup>-1</sup> in farms which had never sprayed with fungicides to an average of 175 and 83 mg kg<sup>-1</sup>, respectively. In both coffee and vegetable, fields Cu and Zn contents differed among sites and that fields sprayed for prolonged periods contained elevated amounts of these elements. Distribution pattern within the plough-layer and metal contents within the individual farms were found to be closely related to duration of application, type of fungicides used, degree of management within the individual farms, and nature of the topography especially in coffee farms. It was also concluded that organic matter contents played a major role in controlling the concentration of heavy metals in both coffee and vegetable fields.

**Key words:** Cu, DTPA, plough-layer, Zn

### **Heavy metal levels in Kiwira coal mining area in Tukuyu, Tanzania**

Mndeme, U.M.

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A study was conducted to determine and document the status of heavy metals in Kiwira mining complex in Tanzania. There were variations in metal contents between the coal grades and its combustion by-products as well as sampling times. There was slight enrichment of metals in soil within and around the mining complex, though no clearly defined trends were observed with increasing distance from the mining complex. Non-significant relationships were observed between DTPA-extracted heavy metals and selected soil properties with the exception of Ni, Cu, Pb and Mn which were significantly correlated with pH. Plant metal contents were relatively low and had poor correlation with the soils metal contents. It was only plant Ni content, which gave positive correlation with soil total Ni content. The heavy metal

contents in waters and wastewaters were below the detectable limits, while Ca and Mg were present in high concentrations. However, some heavy metals (Zn, Ni and Mn) in sediments showed significant differences between sampling locations.

**Key words:** Cd, Cr, Cu, Pb, Se

### **Cottage industry heavy metal pollutions of Nairobi River area in Kenya**

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Heavy metal pollution of Nairobi River in the Ngara-Gikomba areas and their environs due to influx of wastes from cottage industries was studied. Surface (0-15 cm) soil samples were obtained from cottage industry locations between 0 and 1000 m away from the centres of the installations. Plants were sampled at 5-320 m away, whereas sediment and water samples were drawn from the Nairobi River between Chiromo and the downstream end of Gikomba. The cottage industries caused significantly ( $p < 0.05$ ) high levels of heavy metals in soils receiving wastes. Heavy metal accumulations depended on the type, intensity and duration of activity of industry; and distance from activity centre. There were significant ( $p < 0.05$ ) correlations between EDTA-extractable Pb, Cu and Zn and percent OC and percent Clay of the soils. Most metals in *Amaranthus* were significantly ( $P < 0.05$ ) correlated with total soil metal levels, but very few with EDTA-extractable metals. Significantly ( $p < 0.05$ ) high metal levels in sediments and waters from Nairobi river were contributed by the wastes from cottage industries.

**Key words:** Amaranthus, Cd, Cu, EDTA, Pb

### **Lands as thematic mapper and ancillary data for assessment of soil erosion on Uluguru Mountains in Tanzania**

Mboya, T.O.

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Conventional field surveys for the establishment of soil erosion maps can be greatly improved if combined with remote sensing techniques. In this study, data acquired by remote sensing techniques (i.e., aerial photos and satellite images) were used, alongside field checks in assessing soil erosion on the western slopes of the Uluguru Mountains in Tanzania. *Farming area B*, *grassland A* and *Grassland B* were the most severely eroded of all the land cover types studied. Features observed included large areas under cultivation on steep slopes, complete removal of surface horizons and prominently exposed roots of trees and grass tufts. ERDAS software was used to analyse the Landsat thematic mapper <sup>TM</sup> imagery. Computer pattern recognition techniques were then used to analyse the imagery of the sample area and spectral classes representing different cover types derived. The spectral classes were then matched to the vegetation cover classes produced from aerial photographs. Only 25% of the spectral classes had strong correlation with the land cover classification map. This was mainly due to the effect of shadows which covered about 30% of the satellite image thereby limiting accuracy of computer pattern recognition.

**Key words:** Aerial photos, grassland, remote sensing

### **Characterisation of antibiosis activity of *Streptomyces* from soils of different ecological zones in Tanzania**

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The population and types of *Streptomyces* in different ecological locations of Tanzania were evaluated at Mkuyuni in Morogoro region, Kibaha (Coast region), Kitulo (Iringa), and Chimala (Mbeya). There was no significant ( $p < 0.05$ ) difference in *Streptomyces* populations among the soils when the plating medium was adjusted to pH 7.1. However, significant differences were observed at lower pH values. The populations increased significantly from a  $\log_{10}$  value of 4.6 to 5.19 when adjusted pH varied from 5.7 to 7.1, respectively. The highest population was at pH 6.2, with a  $\log_{10} = 5.29$ . The soils organic carbon content had significant 90.01% negative influence on the populations, while clay content a positive influence. The spore chains of the *Streptomyces* were Flexuous, Rectus, Retinaculum-Apertum, Spiral or Monoverticillus, whose frequencies of occurrence were 11.11, 12.69, 15.87, 57.14 and 3.17%, respectively. The aerial mycelia were blue, creamy, gray, pink, red and white with frequencies of 13.43, 2.98, 58.20, 5.97, 2.98 and 16.41, respectively. About 65% of the isolates produced brown soluble pigments. Others were violet (2.75%) and yellow (8.77%), with 33.33% of the isolates producing no pigments. The *Streptomyces* had differential ability of inhibiting growth of the plant pathogens *Acidovorax avenae*, *Clavibacter michiganensis* sub sp michiganensis, *Xanthomonas oryzae* pv. *Oryzae*, *X. vasicatoria*, *X. campestris*, and *X. phaseoli* var fuscus. Some (27%) of the *Streptomyces* isolates inhibited up to three pathogens, while 12.32 inhibited all pathogens tested. The animal pathogens, *Salmonella gallinarum*, *Staphylococcus aureus*, and *Streptococcus agalactiae* were also inhibited. Some (33%) of the *Streptomyces* inhibited one or other of these pathogens while 5.55% inhibited all. Overall, more than 90% of the *Streptomyces* isolates inhibited growth of some of the pathogens tested.

**Key words:** *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*

### **Influence of *Ngoro* cultivations on depression moisture storage and maize performance in Tanzania**

Mogasa, P.M.

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A field experiment was conducted on a slope of 30% on the foothill of the Uluguru Mountains in Morogoro, Tanzania to evaluate the influence of *Ngoro* cultivation system on soil moisture storage and maize yield. Three shapes of the *Ngoro* pits namely: Shape 1 (rectangular with the longest side across the slope), Shape 2 (rectangular with the longest side along the slope), and Shape 3 (square) were compared with flat cultivation, a common practice in the study area. The *Ngoro* shapes stored at least 1.36 times more soil moisture than flat cultivation ( $p < 0.05$ ). The position of the ridge on the four sides of the pit had no significant effect on soil moisture storage ( $p < 0.05$ ). *Ngoro* cultivation showed significantly higher soil organic matter than flat cultivation. Top soil (0-10 cm) had 15% organic matter compared to 7 and 6% at a depth of 10-20 cm and 20-30 cm, respectively. Bulk density was significantly lower in the *Ngoro* compared with flat cultivation. Shape 1 had significantly lower depression storage compared to Shapes

2 and 3 ( $p < 0.05$ ). *Ngoro* cultivation produced 66% more grain yield than flat cultivation. The position of the ridge on the slope had no significant effect on maize grain yield.

**Key words:** Bulk density, organic matter, ridge position

### **Soil salinity associated with sugarcane production under irrigation in Moshi, Tanzania**

Kiwale, A.A. (1999)

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In Tanzania, the problem of salinity and sodicity is common and widespread, especially in the irrigation scheme of the Tanganyika Planting Company Ltd in Arusha. A study was carried out to investigate the distribution, origin and characteristics of salt affected soil in Chini-Moshi (TPC). It was observed that the soils were young profiles, of deep alluvial deposits. The soils were classified as Humic Cambisols; Eurtric Gleysols and Calcaric Fluvisols in South, North and West areas of TPC, respectively. The main categories of soils in TPC were normal soils in north and west areas; Saline (fields 19A and 21d) and sodic (80%) soils in South area; Saline sodic soils in field R8 in West area. Kikuletwa river water showed a potential to and cause soil salinity with electric conductivity values of 0.95 and 0.48  $\text{dS m}^{-1}$  in first and second water sampling respectively. Ruvu and Weruweru waters were medium and low in salinity levels, with values of 0.35, 0.16 and 0.07, 0.1  $\text{dS m}^{-1}$ , respectively. All the rivers had low sodium, With 19.71, 11.9 and 3.33  $\text{mg kg}^{-1}$  in Kikuletwa, Ruvu and Weruweru rivers respectively.

**Key words:** Alluvial, electrical conductivity, sodic

### **Copper fungicide use and accumulation in beans in Morogoro District in Tanzania**

Tiluhongelwa, T.D.M.

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This study was conducted to assess copper accumulation in vegetable growing soils of Mgeta in Tanzania due to fungicides and its (Cu) uptake by beans grown in rotation with tomatoes. About 62.7% of the farmers engaged in vegetable production reported to have used copper fungicides. Copper was significantly ( $p < 0.05$ ) higher in fungicides-treated sites than in non-treated sites (controls). In all sites and all depths, copper content increased with duration of fungicides use. DTPA-extractable copper in the top soil (0-5 cm) increased from 0.3  $\text{mg kg}^{-1}$  in farms that had never been sprayed to 14.4  $\text{mg kg}^{-1}$  in farms sprayed for 5-10 years. Total copper in the top soil (0-5 cm) increased from 21.4  $\text{mg kg}^{-1}$  in non-sprayed to 62.55  $\text{mg kg}^{-1}$  in farms sprayed for 5-10 years. Extractable Cu or total Cu decreased with depth in all categories of fungicide use. Copper contents were found to correlate with soil pH, clay and organic carbon. The growth of beans in different treatments used was normal, healthy and vigorous. The uptake of copper by beans increased with increasing soil extractable copper. Copper uptake from the 5-10 years of fungicides use was 12.71  $\text{mg Cu kg}^{-1}$  compared to 5.63  $\text{mg Cu kg}^{-1}$  in farms which never sprayed copper fungicides.

**Key words:** Copper uptake, DTPA, tomatoes, top soil

### **Response of maize to nitrogen in major soil types in Kilimanjaro region, Tanzania**

Temba, R.J.M.

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A pot experiment was carried out on different N rates (0, 25, 50, 100, and 200 mg kg<sup>-1</sup> soil) in different soil types, Humic Nitisols, Eutric Fluvisols and Haplic phaeozems with maize as the test crop in Tanzania. It was observed that dry matter yield, percent N in plant tissues and total N uptake for maize grown on the three soils increased with increasing N rates. On the Eutric Fluvisol, response to N fertiliser was high compared to the other soils. The three N carriers increased maize yields in all the three soils indicating that the three soils were deficient in nitrogen. The Eutric Fluvisol with relatively low soil N and nearly neutral pH value showed the highest maize response to N sources as compared to the Haplic Phaeozem and Humic Nitisol. It was clear that CAN was the best N carrier as compared urea and sulphate of ammonia.

**Key words:** CAN, sulphate of ammonia, urea

### **Iron oxide impregnated filter paper method for predicting available phosphorus in paddy soils of Tanzania**

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Experiments were conducted to evaluate the suitability of iron oxide impregnated filter paper (Pi) method for predicting available phosphorus in selected paddy soils of Tanzania. Two versions of the Pi method, namely; directly embedding Pi strips in moist soil or flooded soil (designated as PiPe) and shaking Pi strips with soil suspensions in the laboratory (designated as Pi-P) were evaluated. These methods were compared with Bray-1 and Olsen techniques, which were used in Tanzania. Ten soil samples from selected rice growing areas were used for a pot experiment and one of those sites was used for a field experiment. Good correlations were found between extractable P by pairs of the extracting procedures tested with the correlation between Pi-P from air soils and PiPe from Pi strips directly embedded in moist soils designated as PiPem ( $r=0.98^{**}$ ) being among the highest. The same correlation coefficient was obtained between Pi-Pf (P extracted from soil sample after flooding) and PiPef (P extracted by Pi strips directly imbedded into flooded soils). Olsen P and Bray -1P gave  $r=0.99$  ( $p<0.01$ ). Phosphorus application significantly increased dry matter yield in six soils out of ten tested. Rice (*Oryza sativa* L) response to P was best correlated with Pi-Pf ( $r = 0.76^{**}$ ) followed by PiPef ( $r=0.71^*$ ). Correlation between the two variables for the rest of the P tests were not significant. The Pi-Pf and rice growth data were used to estimate the critical P concentration in soils and gave a value of 22 mg P kg<sup>-1</sup>.

**Key words:** Bray I, Olsen, *Oryza sativa*, Pi-strips

## Zinc and copper status in soils of Sokoine University of Agriculture in Tanzania

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A study was conducted to assess the zinc and copper statuses in the soils of the central part of Sokoine University of Agriculture (SUA) farm. Twelve soil samples were collected from the farm. Zinc and copper in these soils was extracted with four extractants, namely 0.005M DTPA-TEA (pH 7.3), 0.005 DTPA-AB (pH 7.3), 0.1 M HCl and double acid (0.05 M HCl + 0.0125M H<sub>2</sub>SO<sub>4</sub>). Two soils (Oxic Haplustult and Typic Rhodustult) out of the twelve soils were used for glasshouse experiment to determine the response of beans (*Phaseolus vulgaris*) to zinc and copper application. The soils were each treated with Zinc and copper at the rates of 0, 2.5, 5 and 10 kg ha<sup>-1</sup>. Zinc application generally increased the dry matter yield of bean plants. The increases were significant (p<0.05) compared to the control. Copper increased dry matter yield in the Oxic Haplustult. However, a negative response was observed in the Typic Rhodustult. Zinc and copper tissue concentrations in bean shoots and their uptake were significantly increased in both soils by the application of zinc and copper. However, the tissue zinc and copper concentrations observed were rather high and above the critical concentrations reported in the literature. Of the four extractants tested, 0.005M DTPA-TEA gave significant correlations with dry matter yield, tissue zinc concentrations and zinc plant uptake. However, none of the methods was found to be suitable for the extraction of copper in these soils.

**Key words:** DTPA-TEA, Oxic Haplustult, *Phaseolus vulgaris*

## Influence of soil properties on dissolution of Minjingu phosphate rock in Tanzania

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Phosphorus is mostly supplied in the form of water-soluble fertilisers, which are very expensive in Sub-saharan Africa. A study was conducted to investigate the extent of Minjingu phosphate dissolution and extractability of P in eleven Tanzanian soils. P adsorption maxima of the soils ranged from 375.4 to 4110.2 mg P kg<sup>-1</sup> and were directly influenced by Al<sub>2</sub>O<sub>3</sub>. The amount of P adsorbed at 0.2 mg P ml<sup>-1</sup> ranged from 22 to 710 mg P g<sup>-1</sup>. The soil with the highest P adsorption maximum had the highest P adsorbed at 0.2 mg P ml<sup>-1</sup>. On the other hand, soils with substantial amount of P in equilibrium solution at zero added P had low P requirement. The extent of MPR dissolution in the eleven soils ranged from 34-97% of the applied P after 70 day of incubation. Of the variation (83%) in MPR dissolution was accounted for by three soil properties, namely, percent Ca saturation, OC and P retention capacity. Bray 1 P in the experimental soils ranged from 7.3 to 71.0% of the dissolved P after 56 days of incubation, suggesting a high degree of fixation. Bray 1 P also significantly related to exchangeable Al, Al saturation, soil pH, soil pH buffering capacity and OC. However, none of these soil properties accounted for >50% of the variation in Bray 1 P.

**Key words:** Adsorption, Al<sub>2</sub>O<sub>3</sub>, aluminium, organic carbon

### **Effect of Minjingu phosphate rock and selected plant biomass on phosphorus availability in soils with contrasting properties in Tanzania**

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Incubation and field experiments were initiated to assess the influence of combining Minjingu rock phosphate (MPR) with *Gliricidia* (GLC) and maize stover (MS) on the availability of P in Magadu and Kilosa soils in Tanzania. The pH of Magadu soil was 4.9, while that of Kilosa was 6.2. The treatments were ABS (absolute control), MPR, MPR+GLC, MPR+GLC+MS, and TSP (triple superphosphate), TSP+GLC, GLC, GLC+MS, MS. The treated samples were incubated for 42 days and a sub-sample from each treatment was withdrawn periodically for NaOH P and Bray 1-P determination. Addition of plant biomass did not improve NaOH P in the two soils. The results indicated that Bray 1 P from MPR treatments was comparable in Magadu and Kilosa soils despite of their differences in the extent of MPR dissolution. Addition of organic materials in the two soils resulted in slight increase in Bray 1 from both TSP and MPR treatments.

**Key words:** Bray 1-P, *Gliricidia*, maize stover, NaOH

### **Sugarcane response to zinc in soils of Tanganyika planting company (TPC) estates**

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A study was undertaken to assess the status of zinc and response of sugarcane to applied zinc in selected estates of TPC. The soils of South, West and North areas were Typic Haplustults, Typic Ustochrepts and Typic Ustochrepts, respectively. The DTPA extractable zinc of topsoils ranged from 0.48 to 2.30, 0.60 to 3.29 and 1.89 to 2.92 mg Zn kg<sup>-1</sup> in south, west and north areas, respectively. In subsoils, the range was 0.20 to 1.94, 0.65 to 2.57 and 0.57 to 1.64 mg Zn kg<sup>-1</sup> in South, West and North areas respectively. Overall, the largest proportion of zinc was associated with the residual fraction (83.2%) based on fractionation. Leaf zinc concentration ranged from 8.04 to 22.56 mg Zn kg<sup>-1</sup>. Foliar application of zinc increased the dry matter yield (DMY) of sugarcane by 2.8 kg ha<sup>-1</sup> and 8.9 kg ha<sup>-1</sup> at 5 and 10 kg Zn ha<sup>-1</sup> rates of applied zinc respectively. Soil application of zinc increased the dry matter yield by 21.55 kg ha<sup>-1</sup> at the 10 kg Zn ha<sup>-1</sup> rate of applied zinc, thus sugarcane response (clone B52-313) to applied zinc was more effective from soil rather than foliar application method.

**Key words:** Dry matter yield, residual fraction

### **Contribution of off-season weeds to supply and conservation of soil nutrients under sweet potato ridges in Tanzania**

Kuhanda, A.H.

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The incorporation of off-season (*syn.* post-harvest) weeds under sweet potato ridges is considered by farmers to improve the soil fertility and consequently, the yield of maize in a

sweet potato-maize rotation at Gairo in Tanzania. A study was undertaken to establish the contribution of the off-season weeds to the regeneration and conservation of nutrients within the soil microbial biomass (SMB). Five weed species occurred in the area. These (with their relative abundance in brackets) were *Bidens pilosa* (47.60%), *Vernonia aemulans* (21.70%), *Erlangea cordifolia* (19.60%), *Tridax procumbens* (7.60%) and *Eragrostis tenella* (3.50). The weed miscellany recycled into the soil 1032.61; 25.85; 1.95; 35.34; 5.94; and 8.07 kg ha<sup>-1</sup> of C, N, P, K, Ca and Mg, respectively. The values of SMB varied widely. Despite this, sweet potatoes gave a consistent though non-significant increase in the SMB. Weeds and ridges also tended to increase SMB, though not as consistently as the potatoes. Based on the SMB-Carbon, estimates of the nutrients conserved in the SMB in the sweet potato plots 91, 65, and 59 mg g<sup>-1</sup> of N, P and K, respectively. The incorporation of the weeds generally did not improve the availability of N or P except (for N) where the weeds were buried under ridges.

**Key words:** Microbial biomass, nitrogen, phosphorus, potassium

### **Rice yields as influence of nitrogen from Azolla- Anabaena association supplemented with inorganic nitrogen in the lower Moshi irrigation project, Tanzania**

Mvukiye, N.E.  
Sokoine University of Agriculture, Tanzania

A field study was conducted in the lower Moshi Irrigation project, Tanzania, to quantify the green-manurial potential of *Azolla* grown as a dual crop with irrigated rice. Parallel studies on the *in situ* decomposition rate of *Azolla* and the effect of the rice canopy on *Azolla* N accumulation were also undertaken. *Azolla* alone and in combination with 40 and 80 kg N ha<sup>-1</sup> as urea (45% N) was compared with untreated control or, 160 kg N ha<sup>-1</sup> as urea. These treatments were tested on *Wahiwahi* (indigenous) and IR54 (improved) rice varieties. An inoculation rate of 3 t ha<sup>-1</sup> yielded 19.63 t/ha of fresh *Azolla* in 15 days and contained about 26 kg N ha<sup>-1</sup>. The *Azolla* decomposed very fast, losing 90% of its weight in 3 weeks of incorporation into soil. *Azolla* alone significantly ( $p < 0.05$ ) improved rice leaf chlorophyll; the improvement being comparable to that obtained with *Azolla* supplemented with successive amounts of urea or, 160 kg N ha<sup>-1</sup> as urea alone. Despite its low N contribution, *Azolla* demonstrated considerable potential for promoting rice performance under conditions of the Lower Moshi irrigation Project.

**Key words:** Chlorophyll, decomposition rate, incorporation

### **Effect of rice milling by-product mixture and fertiliser nitrogen on yields of flooded rice at Simbo in Tanzania**

Mabula, L.C.  
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A study was conducted at Simbo, Igunga Tanzania to evaluate the effects of a rice milling by-product (RMB), with fertiliser nitrogen [(NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>] on the growth and yield of flooded rice. The RMB is a popular soil amendment in Igunga and is claimed to increase rice yields. Rice

husk constituted the largest proportion 976%) of the RMB mixture. The RMB was also nitrogen-poor (C:N ratio = 44.1). Although  $(\text{NH}_4)_2\text{SO}_4$  consistently accelerated decomposition of the RMB, this material was largely resistant to decomposition, thus, a large proportion (71%) of it remained undecomposed after 12 weeks of incubation. Despite the above characteristics, the RMB substantially improved plant growth and grain yield in both rice varieties (Kahogo-local and IR 8-improved), with or without  $(\text{NH}_4)_2\text{SO}_4$  application. Some (post-harvest) soil properties (organic carbon, available phosphorus and structure) were improved by the RMB. However, this effect was less pronounced on total N, CEC and pH.

**Key words:** C/N ratio,  $(\text{NH}_4)_2\text{SO}_4$ , phosphorus

### **Materials suitable for confection of substrates for raising seedlings in a nursery in Tanzania**

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This study was conducted to evaluate eight local and abundantly available materials for suitability in confectionating substrates for raising seedlings in a nursery. The materials included Pouzzolane, sawdust, sugar cane bagasses, compost, forest soil, sandy soil, rc and coconut fibre. These were formulated into substrates, namely, forest soil: sugar bagasse, pouzzolane: sugar bagasse, coconut fibre: sandy soil, sawdust: pouzzolane, compost: coconut fibre and forest soil: rc. To a larger extent farmers in the villages use compost and forest soil as substrates in the nursery industry. In terms of physical and chemical properties, all materials qualify in substrate confectionate, except sandy soil, pouzzolane which should be modified by mixing them with high value materials (materials with high available water and nutrient holding ability) and coconut fibre which should be added in relatively low quantity due to its high tannin content and exchangeable sodium. In terms of both physical and chemical properties, compost: coconut fibre was the best substrate, followed by pouzzolane: sugar bagasse, coconut fibre; sandy soil, sawdust: pouzzolane, rc: coconut fibre and forest soil sugar bagasse. With respect to chemical properties, compost: coconut fibre is the best substrate, followed by forest soil: sugar bagasse, pouzzolane: sugar bagasse and forest soil: rc.

**Key words:** Bafasse, coconut, pouzzolane, sawdust, sugar

### **Plant nutrients status of soils of Kibena Tea Estates in Njombe district in Tanzania**

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A study was undertaken to assess plant nutrient status of the soil and tea plants of Kibena tea estates in Njombe, Tanzania.. Twenty–three composite soil samples at a depth of 0-40 cm were randomly collected from two estates, namely, Lihogosa and Itambo. The selection of the sampling blocks was done based on the crop performance and visual appearance of the soils. The third leaf from clones, TRK 6/8, BBK 207, Clone 282, and PC 81 were collected from the

plants from points where soils were sampled. Calcium S, Zn and Cu were consistently low in almost all samples. The levels of N, P, K and Mg ranged between low to medium, while Mn and Fe ranked sufficient. Leaf P, Ca, Mg, and Zn were adequate in most samples for tea production. The relationship between soil properties namely, pH, organic carbon, CEC, and exchangeable acidity with macronutrients revealed that the variations of the Zn, Cu, K, and Fe were to a large extent controlled by the pH but the variation of the total bases, Ca and Mg were controlled by the CEC, organic carbon and exchangeable acidity.

**Key words:** CEC, copper, nitrogen, phosphorus, potassium, zinc

### **Effect of time of contact and rates of Minjigu phosphate rock on its dissolution in an oxic Haplustults**

Nsenga, J. V

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A pot experiment was conducted at the Sokoine University of Agriculture Morogoro, Tanzania on the effect of time of contact and rates of Minjigu phosphate rock (MPR) applied to an *Oxic (Kanhaplic) Haplustults* on its dissolution and release of P and Ca for plants. The soil was mixed MPR at rates equivalent to 0, 50, 75, 100, 150 kg P ha<sup>-1</sup>. The incubation period were 120, 90, 60, 30 and zero days prior to sowing the maize (*Zea mays* L. var. Staha). MPR rates increased P release. The increase in the amounts of P released tended to increase with time of incubation up to about 75 days, and decreased thereafter. The amounts of MPR dissolved ranged from 1.17 to 13.11 mg P kg<sup>-1</sup> and 10.74 to 15.91% for extractable P and DP% values, respectively. The interaction between equilibrium periods and MPR rates predicted about 86.8 % of the variation in MPR dissolution. MRP rates predicted about 76.6 % of the dissolution of MRP, while 10.3 % of the dissolution predicted by equilibrium period. The Soil pH and extractable Ca increased slightly with MPR rates but decreased with incubation period. The exchangeable acidity and Al decreased with increase in MPR rates, and slightly with incubation periods. Maize dry matter yields, P and Ca uptakes increased significantly with increase in MPR levels. Plant P and Ca contents decreased significantly with the increase in MPR rates.

**Key words:** Calcium, exchangeable Al, phosphorus, *Zea mays*

### **Environmental pollution by copper fungicides used on coffee in Arusha region, Tanzania**

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This study was undertaken to examine environmental pollution by residues of Cu fungicides in coffee fields of Arusha and Arumeru districts in Tanzania. Soils were analysed from coffee fields sprayed with fungicides for duration of 15 – 20 years to over 50 years under both small and large-scale cultivation. Young bean plants and their associated soils were collected from randomly selected coffee fields based on the duration of fungicide use. Both total and DTPA extractable Cu increased with increased frequencies, amounts and duration of Cu fungicide

use. Copper was significantly ( $p < 0.05$ ) higher in fungicide-treated sites than in absolute control (virgin forest) soils. Bean plants from fungicides-treated coffee fields had high levels of Cu samples collected from control soils. Plant Cu concentrations and uptake were significantly ( $p < 0.05$ ) correlated with Cu content in soils. Slopes contributed to transportation of Cu through erosion, with higher levels of accumulating downslope. Water and sediments from Lake Duluti were found to have levels of Cu comparable to natural background levels.

**Key words:** Bean, DTPA, forest soil, slope

### **Conservation measures, properties and productivity of volcanic soils on slopes of Mount Meru, in Tanzania**

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A study was conducted to examine the effect of soil conservation measures on soil properties and productivity of volcanic soils on the slopes of Mount Meru Region. The experiment was conducted in two agroecological zones, namely: medium (1,400-metres above sea level (m.a.s.l.) and high (1,700 m.a.s.l.) altitude zones. Two commonly used soils conservation measures, *Fanya Juu* and Contour bunds, were tested against non-conserved plots. Soil conservation measures had no significant effect the surface soil pH, CEC, exchangeable based, total nitrogen, available phosphorus and organic matter. The depth of Ap horizon in the conserved plots was not significantly different ( $p < 0.05$ ). However, uncovered plots registered the lowest topsoil depth and they were significantly different from conserved plots. Mean bean yield ranged from 789 kg ha<sup>-1</sup> in unconserved to 1,367 kg ha<sup>-1</sup> in *Fanya Juu* terraced plots. *Fanya Juu* treatments significantly out-yielded ( $p < 0.05$ ) contour bund plots by 127 kg ha<sup>-1</sup>. *Fanya Juu* terracing resulted in two folds grain yield compared to control. Conserved plots had higher profile moisture content throughout the growing season. However, soil moisture profile did not differ significantly ( $p < 0.05$ ) between *Fanya Juu* and Contour bund plots.

**Key words:** *Fanya Juu*, nitrogen, organic matter, phosphorus,

### **Industrial wastes as sources of plant nutrients in Morogoro district, Tanzania**

Ndaki, S.M.M.

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A study was conducted at Magadu, Morogoro in Tanzania to evaluate the industrial wastes as alternative sources of plant nutrients and/or soil conditioners. The soil of Magadu is an Oxic Haplustult, which was strongly acidic (pH of 5.1). Total N, available P, %OC, exchangeable Ca and Na, CEC, and DTPA extractable Zn were in the low range. Exchangeable Mg was in the medium range, while exchangeable K, DTPA extractable Fe, Mn and Cu were high. The rates of waste application were 5.24, 4.8, 4.25, 4.5 and 3.7 tonnes ha<sup>-1</sup> of waste tea, wattle bark chippings, waste tobacco, wood ash and saw dust, respectively. Maize dry matter yields were significantly higher in plots which received 5.24 tonnes ha<sup>-1</sup> of waste tea, followed by plots treated with 4.25

and 4.5 tonnes ha<sup>-1</sup> of waste tobacco and wood ash, respectively. Grain yields were significantly higher in waste tea and wattle bark chippings plots than in the other waste amended plots. Soil pH, available water capacity, available P, %OC, total N, exchangeable bases, CEC, DTPA extractable Zn and Cu in waste amended plots increased in the top 15 cm of soil relative to the control plots. DTPA extractable Fe and Mn, exchangeable Al and acidity were significantly reduced in all waste treatments. Total N and % OC in wood ash and saw dust amended plots were at par with those found in control plots. Waste application on a long term basis will allow good build up of soil organic matter and plant nutrients which in turn will improve on soil productivity.

**Key words:** CEC, tobacco, wattle bark, wood-ash

### **Ethylene dibromide for control of white grubs of sugarcane in Moshi, Tanzania**

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The effect of ethylene dibromide (EDB), a commercially used soil fumigant, was assessed in controlling the white grubs and its impact on *Cordyceps*. Also the contribution of *Cordyceps* as the biocontrol agent of white grubs was evaluated both in fields and in the laboratory. The populations of white grub pest of sugarcane, and that of *Cordyceps*, a naturally occurring fungal pathogen of white grubs, were determined in the four fields of the TPC sugarcane estate. White grubs populations varied significantly ( $p < 0.05$ ) among fields with grub densities varying from 25 000 to 93 000 grubs per hectare. Similarly, the populations of *Cordyceps* differed significantly ( $p < 0.05$ ) between fields ranging from 600 to 4000 *Cordyceps* clavae per hectare. Ethylene dibromide significantly ( $p < 0.05$ ) reduced the populations of both white grubs and *Cordyceps* in treated plots, with maximum impacts at the third week after EDB application. In the laboratory, reduction in the population of white grubs by EDB was consistent to the sliding scale of concentration. Although EDB reduced significantly the germination of the *Cordyceps* clavae from infected cadavers, its effect on fungal growth and the branching of germinated clavae were not significant. Although estimated mortality of white grubs caused by *Cordyceps* in stress rearing experiment was low (0.27-27 the contribution of the fungus as a natural control agent of white grubs was very high (54-94%).

**Key words:** Biocontrol, cadavers, *Cordyceps*, germinated clavae

### **Suitability of the soils of Madiira Research Institute, Arusha, Tanzania, for the production of soybeans and mungbeans**

Mlahagwa, M.R.

Sokoine University of Agriculture, Tanzania

A field study was conducted to assess the suitability of the soils of Madira Research Institute farm for the introduction of vegetable soybeans and mungbeans in Tanzania. The focus was on fertility status of the soils, and plant uptake of nutrients. The soils were medium acidic, with medium CEC, OC, exchangeable Ca, and Mg; low levels of total N, and high levels of

exchangeable K and Bray-1 P. The DTPA extractable Fe and Cu were above the critical limit, while Zn and Mn were medium. Plant analysis for soybeans showed that P and Zn correlated positively with the dry matter yields, while total N, Ca, Mg, K, Fe, Cu and Mn correlated negatively with the same. Nitrogen, Mg, K, Fe, Cu and Mn correlated positively with grain yields, while Ca, Zn and P correlated negatively with the same. For mungbeans, N, Mg, K, Zn and Cu correlated positively with dry matter yields, while P, Ca, Fe and Mn correlated negatively with the same. Nitrogen, Mg, K, Zn, Cu and Mn correlated positively with grain yields, while Ca, Fe and P correlated negatively with the same.

**Key words:** Bray I P, Fe, K, nitrogen, Zn

**University of Dar es Salaam,  
Tanzania**

### **Adsorption of nitrate and chloride in Tanzanian soils dominant in allophanic and kaolinitic clays**

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Surface preference study revealed that the soils preferred  $\text{NO}_3^-$  to  $\text{Cl}^-$ . The adsorption of  $\text{NO}_3^-$  increased in the presence of  $\text{Cl}^-$  in the mixture and *vice-versa*. Destruction of soil organic matter prior to equilibration with the electrolyte solutions of different pH values increased the magnitude of  $\text{NO}_3^-$  adsorption at pH 3.3 and 6.0. However, the adsorption of  $\text{Cl}^-$  was decreased by a similar treatment.

**Key words:** Anionic, competition, organic matter

### **Sorption and availability of sulphur in soils of Mbeya Region in Tanzania**

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University of Dar es Salaam, Tanzania

This study investigated the length of equilibration required for a near-complete equilibrium condition of sulphur in the soils of Mbeya Region in Tanzania. Sulphur sorption and availability were studied. The soils contained kaolinite, hydrous iron oxides and amorphous ferri-alumino silicate as the dominant clay minerals. A 48-hour equilibration period was found adequate and was used in the sulphate sorption. The soils differed widely in  $\text{SO}_4^{2-}$  sorption capacity. Soils with high  $\text{SO}_4^{2-}$  sorption capacity had higher positive  $\text{dpH}$  (pH 0.1 N  $\text{K}_2\text{SO}_4$  pH 0.1N KCl) values than those with low capacity. The correlation between amount of  $\text{SO}_4^{2-}$  sorbed and total  $\text{Fe}_2\text{O}_3$ , amorphous  $\text{Fe}_2\text{O}_3$ , amorphous ferri-alumino silicate and organic carbon content of the soils was non-significant. The  $\text{SO}_4^{2-}$  sorption data for most of the soils were fitted to the Freundlich model. In a greenhouse pot experiment, alfalfa (*Medicago sativa*) was grown on eight soils at six S-fertiliser rates corresponding to six adjusted S (equilibrium S) concentrations determined from the  $\text{SO}_4^{2-}$  sorption isotherm. On most of the soils, the alfalfa seedlings growing in the control pots showed S deficiency symptoms, which disappeared as the plant grew older. Sulphur fertilisation increased dry matter yield of alfalfa significantly on four soils. Sulphur fertilisation also increased tissue S and S uptake by alfalfa on all the soils. The external S requirement for 95 percent of the maximum dry matter yield ranged from 0.8 to 8.2 mg S  $\text{ml}^{-1}$ , but it was less than 2.0 mg S  $\text{ml}^{-1}$  on most of the soils. The soil with the lowest  $\text{SO}_4^{2-}$  sorption capacity had a low (but not the lowest) external S requirement. However, there was no consistent direct or inverse relationship between  $\text{SO}_4^{2-}$  sorption capacity and external S requirement. Nine indices of S availability in the soils were evaluated. The phosphate and acetate solutions extracted more  $\text{SO}_4^{2-}$  than 0.01M  $\text{CaCl}_2$  from all the soils.

**Key words:** Alfalfa, availability indices, hydrous oxides

## **Effect of tillage on soil properties, nutrient uptake and maize growth in Tanzania**

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A field experiment was conducted at Uyole, Mbeya in Tanzania, to study the effect of tillage on soil physical and chemical properties, nutrient uptake and maize growth. Treatments consisted of no-tillage, hand-hoeing with crop residue returned, hand-hoeing with crop residue removed, mouldboard ploughing, and disc ploughing followed by disc harrowing. Root and shoot development of maize plants were significantly more vigorous on no-till plots during the first four weeks of growth. Maize plants on NT plots were in most cases taller than on the other plots. At the full silking stage maize plants grown on NT plots still exhibited more vigorous root and shoot development than the other treatments, but grain yield, final top dry weight and harvest index showed no significant differences among tillage treatments.

**Key words:** Hand-hoeing, harvest index, soil moisture

## **Nitrogen and phosphorus effects on growth, yield and nutrient content of rice grown on alluvial soils in Tanzania**

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The effects of N and P application on some chemical characteristics, N and P content and yield of lowland rice cultivar IR8 were studied on an alluvial soil at Mbarali Rice Farm, Mbeya, in Tanzania. Fertiliser rates were 0, 50, 100, 200 kg N ha<sup>-1</sup> as ammonium sulphate and 0, 20, 40 kg P ha<sup>-1</sup> as triple superphosphate. The initial inorganic N content of the soil ranged from 5.76 - 13.00 ppm indicating a low N-supply capacity, whereas the initial available P content was 4.25 ppm. Nitrogen nearly doubled grain yield at 200 kg N ha<sup>-1</sup> due to low N supply in the soil. There was no response to phosphorus application possibly due to confounding effects of initial soil P fertility. Nitrogen supply was highly correlated with N concentration in rice shoots, index leaves at flowering and in the straw, with the best correlation being that between N supply and N concentration in index leaves. The N concentration in index leaves was also very highly correlated with paddy yield. The critical concentrations of N and P in index leaves were estimated to be 2.37 and 0.29% respectively.

**Key words:** Index leaves, paddy rice

## **Makerere University, Uganda**

## **Effect of *Ficus mucoso* canopy on soil chemical properties in banana plantations**

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Growing of bananas (*Musa* species) under *Ficus mucoso* tree canopies has been done by farmers in the Lake Victoria Crescent Region of Uganda, reportedly because the practice gives higher yields. This study was carried out in, Ibulanku sub-County, Iganga District, in Uganda, to determine the effect of *Ficus mucoso* tree canopy on soil chemical properties in banana plantations. Soil samples were taken from four sites with established banana plantations under *Ficus mucoso* trees. Soil sampling was done 2, 4, 6, and 10 m a way from the tree base, and at depths of 0-15 and 15-30 cm. The 10-metre radius fell outside the tree canopy and, hence, acted as a control. In addition to soil analysis, a semi-structured questionnaire was administered to twenty randomly selected farmers who had the *Ficus* banana agro-system, to obtain farmers' perception on the practice. Soil analysis revealed significantly higher levels of soil organic matter (SOM) and exchangeable  $Mg^{2+}$ ,  $K^+$ , and  $Ca^{2+}$  under the canopy compared with open land (without trees). There were significant ( $P < 0.05$ ) difference in levels of available P, total N content and hydrogen ion concentration with or without the tree canopy. However these parameters tended to decrease with distance away from the trees base. In all cases, the top soil had higher values of these parameters than the corresponding sub-soil samples. Farmers applauded the system and expressed interest in assistance that could make the practice more productive.

**Key words:** Lake Victoria, *Musa* sp., soil organic matter

## **Effect of plant density and fertilizer application on growth and yield of *Asparagus***

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*Asparagus officinalis* L. is a crop of growing economic importance world wide. Two field experiments were conducted at Kawanda Agricultural Research Institute (KARI), in Uganda to determine the effect of fertiliser regimes and plant density on growth and yield of asparagus under Uganda conditions. Variety UC 157 F1 obtained from California, USA, was used. In the first experiment, N and K were applied at rates of 0, 112, and 374 kg N ha<sup>-1</sup> and 0, 47 and 62 kg K ha<sup>-1</sup>, respectively. Fern number, diameter and spear weights increased significantly ( $p < 0.05$ ) along with fertilisation. The number of dead ferns decreased with N application, though individual ferns or spear weights responded to the contrary. Fern dry matter yield was not significantly ( $p < 0.05$ ) influenced by the treatments, though it tended to increase with N application. There was a general decline in foliage density with N application, though this was only significant at forty weeks after planting. The number of spears per plant and spear weight were highest without N application. In contrast, plants treated with K tended to produce more spears though the increase was only up to 47 kg ha<sup>-1</sup> application. Spear productivity (yield per unit area) was similarly highest at 47 kg k. Nitrogen and K concentrations in the tissues were not influenced ( $p > 0.05$ ) by application of either nutrients. During the first year of growth, the

concentration of both nutrients in the tissues increased but in the second year, no clear trend was observed.

**Key words:** *Asparagus officinalis*, nitrogen, potassium, Uganda

### **Impact of environmental disamenity on value of land in Uganda**

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Waste management is increasingly popular, especially in developing countries. Land filling is the most common method of waste management in developing countries, but it has various negative impacts. This study quantifies the land impacts of proximity to a land fill in Uganda, as an environmental disamenity using the hedonic price model. The study used primary data on property and other factors including distance from landfill as explanatory variables. Proximity to the landfill significantly affected land value, in that that people were willing to pay more to live far away from the landfill. On the other hand amenities such as accessibility to the nearest public transport stage and city centre increase land values. A concrete policy on location and management of landfills and waste recycling policies should be enacted.

**Key words:** Hedonic price model, proximity to landfill

### **Soil erosion from major agricultural land use types and associated pollution loading in Lake Victoria micro-catchments**

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The quality of water in Lake Victoria is degrading as a result of poor management of agricultural land use. The objective of this study was to (i) identify land-use types loosing the highest amount of soil and nutrients, (ii) determine the soil and nutrient hot spots in Kibaale micro-catchment, and (iii) assess the efficiency of contour bunds as a best management practice in reducing the export of soil and nutrients through surface runoff. The experiment was conducted on 13 runoff plots of 15 m x 10 m installed on four major agricultural land-use types (annual crops, banana, coffee, and degraded rangelands). Contour bunds were constructed at 20-m spacing interval for the four agricultural land-uses. Soil and nutrient losses were monitored for three consecutive years. The contribution of the major agricultural land-use types and hot spot areas were determined through linear mixing box model integrated into AnnAGNPS-GIS environment. The average annual runoff ranged between 3 and 23% of the rainfall input. Degraded rangelands lost relatively higher amount of rainfall water through surface runoff compared to banana and coffee ( $p=0.022$ ). Annual soil loss ranged from 27.7 to 86.7 tonnes per ha per yr and was higher in annuals than banana and coffee ( $p=0.038$ ). Seasonal soil losses contributed more than 75% of the annual losses for all agricultural land-uses. Eroded sediments had higher nutrient concentrations than the remaining soils, and varied with land-use and/or seasons ( $p<0.05$ ). Nutrient and sediment sources budget showed that most of the nutrients and sediments came from degraded rangelands mixed with annuals concerning Total Suspended Solid (TSS) and total phosphorus (TP), and woodlands for total N (TN). Perennial mixed with

annual crops were second in exporting TSS, and third for TP and TN. Grasslands were ranked fourth for TSS, TP and TN. The hot spot areas were well-drained, deep and permeable soils in depressions below Nabunga hill and very compacted grassland on both sides of Mutukula road. Contour bunds reduced soil and nutrient losses significantly ( $p < 0.05$ ). Two different reduction trends were observed, exponential (Annuals and Degraded rangelands) and linear (Banana and Coffee). However, soil loss remained close to the threshold value on annuals and degraded rangelands. Yield increased significantly on all land-use types after the introduction of contour bunds.

**Key words:** AnnGNPS-GIS, beans, nutrient losses, rangelands

### **Effect of slope and land use on runoff and soil loss**

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Soil erosion is a major agricultural and environmental problem in the Lake Victoria Basin. Quantitative data to guide strategic mitigation measures are scanty. Erosion processes are complex, varying among slope magnitudes, land use and soil types. A study was conducted in the Lake Victoria Basin of Uganda on a *Luvisol*, to evaluate slope and land use interaction on runoff and soil loss, and to create a basis for effective soil management asures me. Slope (8, 12 and 16%) and land use: sole banana (*Musa sp.*) and banana-coffee (*Coffea arabica*), were the study factors; while runoff and soil loss were the variables assessed. Runoff and soil loss were significantly ( $p < 0.05$ ) enhanced by slope magnitudes. Runoff for sole banana was 83, 186, 257  $m^3 ha^{-1} yr^{-1}$ , while in banana-coffee it was 62, 189 and 297  $m^3 ha^{-1} yr^{-1}$  at 8, 12, 16% slope magnitudes, respectively. Correspondingly, soil loss values were 9, 36, 48  $t ha^{-1} yr^{-1}$  and 16, 24 and 46  $t ha^{-1} yr^{-1}$ . At all slope positions, sole banana system was the most effective in runoff and soil loss control. This was attributed to farmers' preference to mulch more intensively the sole banana than banana-coffee. All slope positions and land uses had nearly equal potentials for sustainable productivity if managed appropriately. Correlations between runoff and soil loss at slopes 8, 12 and 16%, were explored and in general, strong polynomial functions were established as  $r^2 = 95$  and  $83\%$ ,  $r^2 = 83$  and  $91\%$  and  $r^2 = 94$  and  $84\%$ , for sole banana and banana-coffee, respectively.

**Key words:** Banana, coffee, Lake Victoria, soil erosion

### **Comparative effects of short duration improved fallow legumes on maize yield and soil fertility in eastern Uganda**

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Makerere University, Uganda

There is great concern over declining crop yields in most of sub-Saharan Africa, which has largely been blamed on declining soil fertility. Alternative strategies such as mineral fertiliser application, use of manure (compost and animal) and green manuring have been shown to sustain and increase soil productivity. This study was designed to determine the most suitable legume species for soil fertility improvement and weed suppression based on legume biomass

production and maize yield responses. Six on-farm trials were set up in two sub-counties; Kisoko and Osukuru, and another on-station experiment at the Tororo District Agricultural Training Centre (DATIC) in eastern Uganda. Maize (cv. Longe I) was planted as the test crop. Four green manure legume species were each planted between maize rows in all the plots except the control (maize mono-crop). After harvesting maize, the green manure crops continued to grow for two more months. The above ground biomass of the green manure crops and of weeds was sampled for dry matter determination and the rest were incorporated into the soil during land preparation before planting second maize crop. Production costs for different treatments were determined. Results indicated significant ( $p < 0.05$ ) maize yield increases for crotalaria and lablab treatments of 96.4 and 69.6%, respectively, on farmers' fields after legume biomass incorporation. There was no significant ( $p > 0.05$ ) yield response to all legume cover crop treatments in the on-station experiment in both seasons. The better response of maize yield to crotalaria and lablab was probably due to the soil being poorer at the on-farm compared the relatively better soil on-station. Weed suppression was highest under *Mucuna* (96%) on station and on-farm 86%. There were marginal rates of return to Crotalaria of 73.2% on-station and 1985% on-farm.

**Key words:** Crotalaria, marginal rate of return, mucuna

### **Effect of short-duration crotalaria and mucuna fallows on soil productivity in south-eastern Uganda**

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Crop yields in Uganda are low, principally due nutrient deficiencies. The most limiting elements are N and P and are being depleted at fast rates, especially nitrogen, in the sandy Ferralsols of eastern Uganda. On-farm trials were conducted in eastern Uganda, to determine the effect of short-duration fallow of *Crotalaria grahamiana* and *Mucuna pruriens* on soil fertility and productivity. Mineral N increased following improved fallows though non-significant at most sampling dates *Mucuna pruriens* released the highest mineral N, followed by *C. grahamiella* at Dina's site. On the contrary, *C. grahamiana* released higher N than *M. pruriens* at Geoffrey's site and this variation was attributed to differences in biomass production. There were two peaks of mineral N release; the first and highest occurred around the third week, while the second and smaller one around the tenth week. Natural fallow released higher mineral N than improved fallow and compost manure in minor peak. Mineral N in the major peak was dominated by  $\text{NO}_3^- \text{N}$ , and  $\text{NH}_4^+ \text{N}$  was prevalent in the minor peak. Improved fallows without N fertiliser increased grain yield by 29.3 and 36.0%, following *C. grahamiana* and *M. pruriens*, respectively at Dina's site compared to 22.1 and 15.7% after natural fallow and compost manure. On the other hand, an increase of 56.6 after *C. grahamiana* and 27.2% from *M. pruriens* fallows at Geoffrey's site compared to 29.1 and 8.6% by natural fallow and compost manure, respectively, was realised. However, high variable and opportunity costs rendered improved fallow less profitable at both sites. Improved fallows without N-fertiliser had higher returns to labour than farmers' practices and compost manure had the least financial benefit at both sites as a result of high labour cost.

**Key words:** Compost manure, Ferralsol, improved fallows, nitrogen

## **Transformation of phosphorus in soils amended with phosphate rock**

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Phosphorous is a major limiting nutrients in Sub-Saharan Africa soils, yet P resources exist in the region. Laboratory and greenhouse experiments were conducted to determine the transformation phosphorus (P) from applied Busumbu phosphate rock (PR) under the acidic soils of Mukono, Lugazi and Kabale in Uganda as a basis for explaining P's agronomic potential. Soils were incubated under laboratory and field capacity moisture conditions, with raw and demagnetised PR, and SSP applied at standard phosphate requirement (SPR) of each soil After 1, 3, 6 and 10 weeks of incubation. Application of SSP significantly ( $p < 0.01$ ) increased the labile (bicarbonate and hydroxide) Pi fractions by 90% over the control. Phosphate rock treatments significantly increased the recalcitrant P (HCl Pi and residual P) fractions by approximately 90% in all the soils. Bray I P was significantly higher ( $p < 0.01$ ) for SSP compared to the PR, but declined over time probably because of sorption. There were no significant differences in the PR treatments on Bray I P, however, they both increased extractable Bray I P over the control in Mukono and Lugazi soils with incubation. No liming effect was obtained from PR application. Super phosphate was superior to PR treatments in increasing crop yields. The relative agronomic effectiveness (RAE) indices for the PR types with soybean were  $> 50\%$  except on the Kabale soil, while those for Rhodes grass were less than 50% on the three soils. This shows that the effectiveness of the PR is dependent on both crop species and type of soil. Lack of significant differences between the PR types implied that physical demagnetisation did not increase P availability from the PR. Thus, other beneficiation methods such as partial acidulation need to be explored in order to make this PR a ready source of P for improvement of soil fertility of the four soil P test methods evaluated, Bray II gave the highest significant ( $P < 0.001$ ) regressions with dry matter yield (DMY) and P uptake of both test crops on soils treated with PR and SSP. It was followed by Olsen and bray I methods.

**Key words:** Bray I, labile P, single superphosphate, soybean

## **Evaluation of mineral and organic soil amendments in the rehabilitation of degraded banana fields**

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Banana (*Musa* sp.) is a staple food for over 7 million people in Uganda. Three studies were undertaken in Mukono district, an area with severe *banana* decline in Uganda, to establish an approach for better use of fertiliser inputs in the rehabilitation of soil fertility. The first study involved determination of banana yield responses to nutrients applied in mineral fertiliser form, pre-determined to increase yields from the present levels  $< 5$  to about 15 kg per bunch. Nitrogen, P and K were applied at 0.5, 0.05 and 0.63 kg per mat, respectively, at 12 monthly intervals. In the second study, limiting nutrients to banana production were determined using the major intercrops, maize (*Zea mays*) and beans (*Phaseolus vulgaris*) as test crops. Treatments involved application of N, P, K, NPK, and a control. Nitrogen was applied at a rate of 100 kg per yr to successive crops of maize and beans. The other study examined differences in particulate organic matter (POM) within the surface soils, following annual application of

organic inputs over a three year period to a banana field. Other treatments consisted of a complete control with banana residues removed, banana residues retained, cattle manure applied at 50 kg N per ha with banana residues removed (CM-BR), Napier grass (*Pennisetum purpureum*) applied at 10 t ha<sup>-1</sup> with banana residues removed (NP-BR), cattle manure plus banana residues (CM+BR) and Napier grass plus banana residues (NP+BR). Application of mal-based NPK fertiliser package increased bunch weight from 5.2 to 11.2 kg per bunch ( $P < 0.05$ ) within one year of application. This approximates to an increase of 12 t ha<sup>-1</sup>, which was less than the targeted. This was attributed to moisture stress, nutrient losses by different soil processes and pest and diseases. The limiting nutrient trials showed significant positive maize and bean responses to fertiliser application. Yield from P and NPK treatments were similar and superior to those of N and K treatments, implying that P was the primary limiting nutrient to these intercrops. The addition of organic amendments significantly increased soil particulate organic matter, which in turn, had a positive influence on the soil biological properties, leading to significantly ( $p < 0.05$ ) higher banana yields (22.4 t ha<sup>-1</sup>), compared to 11 t ha<sup>-1</sup> with no organic amendments. Higher yields (18.6 and 17.4 t ha<sup>-1</sup> for CM+BR and NP+BR, respectively) were obtained on combining banana residues with other organic amendments than when the organic amendments were applied as single amendments.

**Key words:** Bean, maize, nitrogen, phosphorous, potassium

### **Characterisation of the spatial variations in soil properties and crop yields across bench terraces of Kabale district in Uganda**

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Terracing is a historical practice in the highlands of south-western Uganda. A study was conducted to investigate the soil factors responsible for the crop yield variations across bench terraces in Kabale in Uganda. Five transects representing five ridges were studied. Each transect was divided into lower and upper positions. Three fields were selected from each transect position. On each field, five strips of 10 m x 1 m running across the field were equidistantly laid out from the upper to the lower field sections. Sorghum (*Sorghum bicolor*) yields and the soil properties of the strips were determined for two growing seasons. A greenhouse experiment was also conducted using soils taken from the upper, middle and lower parts of fields. Sorghum biomass and grain yields differed significantly ( $p < 0.05$ ) between the strips and increased down the fields. The lower two strips contributed 63 and 72% of biomass and grain yields, respectively; while the upper two had 20 and 12%, respectively. Soil bulk density, clay fraction, and K were decreased down the field, while, organic carbon (OC), total N, Ca<sup>2+</sup>, sand (%) and saturated hydraulic conductivity increased down field. The most limiting soil factors to crop production on a bench terrace differed depending on position. Upper parts of the terrace had mostly soil physical limitations, notably clay, bulk density, hydraulic conductivity; and sometimes chemical limitations mainly calcium. The lower sections of fields had soil chemical limitations, notably low phosphorus and potassium. Fields on the upper ridge transect position had significantly higher values of OC, N and lower K<sup>+</sup>, Ca<sup>2+</sup> and clay compared to the lower ridge position. Linear trends for biomass, grain yield, total N and OC, and sand (%) on the lower ridge position were significantly ( $p < 0.05$ ) different from the fields on the upper ridge position.

**Key words:** Bulk density, hydraulic conductivity, sorghum, strips

## **Influence of coffee husks on the availability soil nutrients and pineapple yield**

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The use of coffee husks as a soil input in pineapple (*Ananas comosus*) production is on the increase in the coffee-based agro-ecological zone of Uganda. This practice, though, is not supported by research was conducted to investigate the decomposition characteristics of coffee husks under field conditions. The study was carried out at Mukono District Farm Institute in Uganda. Two types of coffee husks were studied, i.e., undecomposed (freshly hulled) and semi-decomposed husks (left heaped in the open for one month), when incorporated into, and surface applied to the soil. There were no significant ( $p > 0.05$ ) differences between dry matter and nutrient loss of the two types of coffee husks. For both materials, the losses of  $K^+$  and  $Mg^{2+}$  were not influenced significantly by placement method.  $T_{50}$  for the release of  $K^+$  and  $Mg^{2+}$  was 23 and 29 days, respectively. For N, P and  $Ca^{2+}$ , the losses were faster when the materials were incorporated than surface applied. The slowest release rates were exhibited by the  $Ca^{2+}$  in the incorporated material and by N in the surface placed husks. Mineralisation results showed that incorporated materials continued to immobilize N, in amounts ranging from 7.16 to 16.35 kg ha<sup>-1</sup>, during the first 2 weeks; the highest immobilisation being at the rate of 100 t ha<sup>-1</sup> of coffee husks application. In the surface treatments, however, there was a net N mineralisation (6.36 kg ha<sup>-1</sup>) in the first 2 weeks of sampling. In the succeeding weeks of the wet season, the incorporated materials released more N than their surface counterparts. In the last 2 sampling weeks (6 and 8 weeks) of the rainy season, the 60, 80 and 100 t ha<sup>-1</sup>, released more mineral N than the other rates at both placement methods. In the dry season, N mineralisation rates for both incorporation and surface application treatments were not significantly different from those of the control, implying that mineralisation of the materials were minimal.

**Key words:** *Ananas comosus*, immobilisation, mineralization, Uganda

## **Effect of coffee husks placement on distribution of nutrients and microbes in a banana-cropped soil**

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Banana (*Musa* spp.) is a major crop in most parts of Uganda. Its production, however, is rapidly declining thus threatening food security. Decline in soil fertility is among the causes. A study was conducted to assess the cumulative effect of coffee husks on bio-chemical properties of a soil profile in a 6-year old banana plantation at the Makerere University Agricultural Research Institute, Kabanyolo, in Uganda. Coffee husks were applied annually over the experimental period at the rate of 144 t ha<sup>-1</sup> (dry weight basis). Treatments included three application methods, namely, 100% surface, 50% surface plus 50% incorporated, 100% incorporation, and a control (without coffee husks). Two local highland banana cultivars, namely, Nfuka and Mbwarzirume, both of AAA genotypes were the test varieties. Generally, soil bulk density increased with soil depth. There were significant ( $p < 0.05$ ) treatment effects on SOM, total N, Bray-I P, exchangeable  $K^+$ ,  $Ca^{2+}$  and  $Mg^{2+}$  in most soil layers. However, there were no such effects on the concentration of  $H^+$  and content of  $NH_4-N$  and  $NO_3-N$ , at least in

the 0-60 cm soil depth. Generally, SOM and nutrient contents decreased with depth in the soil profile, irrespective of treatments. Incorporation of coffee husks resulted in the highest ( $p < 0.05$ ) nutrient contents in the soil profile. Coffee husks application significantly increased DMY in corms, pseudostems and leaves of both banana cultivars. The 50% incorporated plus 50% surface placement method tended to give highest DMY, which was generally higher for Nfuka than for Mbwarzirume. Coffee husks application did not significantly ( $p < 0.05$ ) influence nutrient contents in plant organs, though nutrient content was higher in Nfuka than in Mbwarzirume cultivar. Coffee husks significantly increased the population of nitrifiers, especially in the 0-40 cm soil layers, where placement methods had no significant differences. Effects of coffee husks application on the population of colony-forming bacteria were similar to those of the nitrifiers. However, the 100% incorporation method had significant increases in populations of colony-forming bacteria even in 80-100 cm soil layer. Furthermore, coffee husks application significantly increased populations of colony-forming fungi in 0-60 soil layers. In addition, placement methods generally had significantly ( $p < 0.05$ ) different effects on the number of these fungi in most soil layers.

**Key words:** *Musa* spp., nitrate, nitrifiers, soil fertility

### **Temporal land use and soil property interrelationships in Wanale and Manafwa catchments of Mountain Elgon in Uganda**

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Land use change is a factor underlying sustainable productivity of cropping systems in various cropping systems in the highlands of Uganda. This study was conducted in Mbale district, in the Wanale and Manafwa catchments in eastern Uganda, to evaluate the temporal land use and soil property interrelationships on the slopes of Mt. Elgon. Data were collected using satellite images and aerial-photo interpretation, ground truthing, field observations, surveys and questionnaires. Data were also collected on historical changes in land use, effects of the land cover/use change, relationship between the land use change and soil properties, problems related to land use change, intensity and the extent to which forest encroachment has taken place. A significant change in land cover/use occurred between 1960 and 2002, but without significant difference among years. Land use change led to significant changes in the soil properties, especially the organic matter and nitrogen levels. Soil loss was experienced as high and very high for the land uses that did not have or had less vegetation cover (bare land and annual). The largest area (53%) was predicted as experiencing very low to low soil loss. Some land uses disappeared for example grazing land, while the encroached forest and bare were due to human activities. The land use changes from the natural primary forest to other land use categories led to the reduction in all the soil properties, especially soil organic matter and nitrogen levels in the different land uses and soil depths.

**Key words:** Nitrogen, organic matter, soil loss, Uganda

## Topsoil depth-banana yield relationships on a Chromic Luvisol in a Lake Victoria basin micro-catchment

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Banana's extended harvest period and perennial nature render the crop a crucial factor in the food security. The objectives of this study were to evaluate the relationships between yields of cooking-type banana and existing top soil depth (TSD); and to assess the most limiting factors for banana production on a Chromic Luvisol in Bukoto County in Uganda. A Geographical Information System (GIS)-aided soil survey was used to establish TSD classes 1, 2, 3 and 4, respectively described as 'very deep' (TSD < 30 cm), 'deep' (25 < TSD < 30 cm), 'shallow' (20 < TSD < 25 cm) and 'very shallow' (TSD < 20 cm), along four 400-m transects on upper back slopes. Ten to fifteen-year old banana fields were selected at 14 sites spread through the TSD classes. In each field, 3 plots measuring 10 m x 10 m were demarcated for triplicate data collection in the Lake Victoria Basin (LVB) of Uganda. Topsoil depth was significantly related to banana yields ( $r^2=53.5\%$ ,  $p<0.05$ ) and its diminution was associated ( $r^2=68.2\%$ ,  $p<0.05$ ) with reduction in banana bunch weight. Bunch weight for cultivars *Nakinyika* (9.74, 12.77, 13.85 and 16.16 kg in class 4, 3, 2 and 1, respectively) and *Nabusa* (7.12, 9.92, 11.3 and 15.88 kg in class 4, 3, 2 and 1, respectively) significantly ( $p<0.05$ ) reduced in the shallow TSD classes. Simulated loss of the surface 5 mm of topsoil resulted in banana yield reduction ranging from 3.3 to 17.5% (or 52 fifteen kg bunches per hectare), depending on the antecedent TSD, and soil and water management level, which significantly limited banana production on the Chromic Luvisol in the LVB. Topsoil dry bulk density and clay content increased, while total porosity, 0.33-bar moisture content and plant available water capacity decreased in the shallow TSD classes. Exchangeable  $K^+$  was sub-critical across all TSD classes, but foliar  $K^+$  was optimal in class 1, low in 2 and 3, and deficient in 4, due to changes in soil physical properties.

**Key words:** Bunch weight,  $K^+$ , soil water

## Effect of nitrogen fertilisation on the quantitative and of sunflower on a ferralisol

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Experiments were carried out to assess the response of three sunflower (*Helianthus annuus* L.) varieties (S401, S430 and Peredovik) to four levels of fertiliser nitrogen (0, 40, 80 and 120 kg  $ha^{-1}$ ) in central Uganda. Nitrogen application increased yields up to a peak. Highest dry matter production was obtained up to 40 kg N  $ha^{-1}$ ; beyond this N levels depressed plant dry matter yields. Addition of P and K enhanced sunflower response to N. The rise in N levels significantly ( $p<0.05$ ) increased crude protein content of sunflower plants. Nitrogen application increased grain yield up to 40 kg N  $ha^{-1}$ . Uptake of N, P and K was generally enhanced by increased levels of these nutrients in the soil. Nitrogen recovery values revealed an apparent loss. Basing on soil tests carried out before and after the study, sunflower growing generally tended to alter the chemical properties of the soil.

**Key words:** Crude protein, *Helianthus annuus*, nitrogen recovery

### **Characterisation of spatial prevalence and contribution of malaria to paddy rice yield loss in eastern Uganda**

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Malaria is one of the water related diseases believed to reduce the available labour in agriculture, especially in paddy rice farming system which serves as breeding grounds. The breeding habitats, their bio-physical properties and the effect of malaria on rice yields are, however, not well characterised. This research aimed at identifying and characterising the anopheles mosquito breeding habitats' bio-physical properties. It also aimed at establishing the cause-effect relationship between malaria-induced labour losses. The study was conducted in Nankoma, Nabukalu and Buluguyi sub-counties in Bugiri district, a paddy rice growing area in eastern Uganda. Data for habitat identification and characterisation were collected every after 25 days, for a period of one year. The Shallow Skim Dipping method was used to sample the anopheles mosquito larvae from breeding habitats. Results indicated presence of significant ( $p < 0.05$ ) numbers anopheles mosquito larvae in straws, side ditches, worm holes, weeds, tyre print, tilled land, hoof print, and paths. Pearson correlations results between variables and anopheles larvae  $\text{dip}^{-1}$  were 0.17, 0.437, 0.193, -0.357, -0.393, -0.329, 0.356, and -0.329 for water depth, turbidity, temperature, paddy density, paddy height, oxygen content, electrical conductivity and number of rice tillers, respectively. Stepwise regression analysis indicated that turbidity, water electro-conductivity, rice height, water depth, water temperature, number of other organisms and rice density, significantly ( $p < 0.05$ ) explained the number of anopheles mosquitoes in a given habitant. Malaria significantly affected the farmers' expected paddy rice yield; reducing it by from 2,480 to 1,170  $\text{kg ha}^{-1} \text{ season}^{-1}$  ( $p < 0.05$ ). Labour requirements results indicated that nursery preparation, land preparation, transplanting, weeding, bird scaring and harvesting required 5.53, 141.65, 101.12, 99.36, 30.25 and 78.0 person day's  $\text{ha}^{-1}$ , respectively. Sensitivity results indicated that labour loss during nursery preparation, land preparation, transplanting, weed control, bird scaring and harvesting led to a yield loss of 45, 24.6, 63.3, 42.4, 104.6 and 43.5  $\text{kg ha}^{-1} \text{ person day}^{-1}$ , respectively.

**Key words:** Anopheles, turbidity, disease, labour, mosquito

### **Enhancement of cattle manure quality and utilisation for crop production on smallholder systems in Central Uganda**

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There is widespread soil productivity decline in Sub-Saharan Africa attributed to low nutrient stocks and negative nutrient balances. In Uganda in particular, this is due to continuous cultivation and crop harvest without due attention to fertility management. A study was conducted on smallholder intensive (IS) and semi-intensive (SEI) cattle management systems in Central Uganda to: (i) establish seasonal changes in quantity and quality of available cattle manure; (ii) enhance cattle manure nutrient quality conservation; (iii) rationalise integrated cattle manure and inorganic nutrient sources for crop production; and (iv) evaluate the economic sustainability of integrated use of cattle manure and inorganic fertiliser sources for crop production. Informal survey, on-farm trials and participatory evaluation of economic

sustainability for integration of cattle manure and inorganic fertilisers were employed. Seasonal changes occurred in cattle manure quality and quantity under both smallholder cattle management systems. The wet season was superior to the dry season for both cattle management systems. Under the IS, total OC, N, P and K were nearly twice that of the corresponding quantities in cattle manure under SEI. The available cattle manure per tropical livestock unit (TLU) per household per year under IS was nearly three times more than under SEI system irrespective of season. Farmers preferred the improved cattle manure management practices to their own practices. The total OC, N, P and K under the improved management practices was twice the respective quality of manure under farmers' management practices, irrespective of management systems. Total OC, N and P decreased significantly ( $p < 0.05$ ) after 4 weeks of retention by 26 and 55, 65 and 58, 51 and 57% in cattle manure from IS and SEI, respectively. The integration of inorganic P with cattle manure improved maize yield under both management systems. Highest stover yields of 15 and 13.9 t ha<sup>-1</sup> were generated where manure was applied at 5 t ha<sup>-1</sup> and 2.5 t ha<sup>-1</sup> plus 20 kg P ha<sup>-1</sup> under IS and SEI, respectively. The highest grain yield of 11 t ha<sup>-1</sup> was produced where manure and P were applied at rates 5 t ha<sup>-1</sup> plus 10 kg t ha<sup>-1</sup> and 5 t ha<sup>-1</sup> plus 20 kg P ha<sup>-1</sup> under IS and SEI, respectively.

**Key words:** Maize, intensive, rainy season, semi-intensive

### **Effect of soil fertility and weed management on the performance of finger millet in eastern Uganda**

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Finger millet (*Eleusine coracana* L. Gaertn.), is among the most important staple crops in Uganda, particular in the drought prone areas of the country. Its unique attributes such as superior nutritional value relative to other cereals; drought, diseases and pest tolerance; and a long shelf life, make it an important food security crop. Soil fertility decline and labour for weed control are among the major production constraints of the crop. This study was designed to explore and formulate a labour-saving weed management strategy under modest nutrients inputs. The study was conducted in Kumi, Pallisa and Kamuli district of eastern Uganda, on nine farmers' fields. Finger millet variety PESE I was the test crop. The experimental design was randomized complete block design arranged in split-plots, with planting method (broadcast or row) as main plots and fertiliser treatments (N, P, kraal manure and N or kraal manure + P) as subplots. The fertiliser treatments were administered factorially at rates of 0 fertiliser/manure kg ha<sup>-1</sup> (control); 45 kg ha<sup>-1</sup> N; 17 kg P ha<sup>-1</sup>; 22.5 kg N + 8.5 kg P ha<sup>-1</sup>, 5 t kraal manure ha<sup>-1</sup> and 2.5 t kraal manure + 8.5 kg P ha<sup>-1</sup>. Row planting was done at the recommended spacing of 30 cm by 6cm, and broadcasting according to the farmers' own practice. Each treatment was replicated nine times (9 farms). Fertiliser application variously influenced finger grain yield. Only the combines application of manure and P or N and P increased finger grain yield significantly ( $p < 0.05$ ) under both row and broadcast planting. Under row planting, however, significant ( $p < 0.05$ ) grain yield increases were only observed in treatments with P alone, P + manure or P + N. Application of N or manure alone had no significant effect, irrespective of planting method. Phosphorus was identified as the most limiting nutrients in finger millet production in this region. Row-planted finger millet clearly out-yielded broadcast plants by about 13% for the best performing fertiliser treatments. Single weeding under broadcast performed the poorest overall. Weeding twice increased grain yield by only 9.7% in row planting, but by as much as

44.7% in broadcasting. Row planting reduced weed population density by about 50% over broadcasting, for all existing weed species. Single hand weeding had greater impact under row planting compared to broadcasting.

**Key words:** *Eleusine coracana*, *Kram mathine*, nitrogen, phosphorus

### **Factors affecting small-scale farmers' adoption of soil fertility management technologies in eastern Uganda**

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Low crop yield due decline in soil fertility and lack of adoption of relevant soil management technologies are major contributors to food insecurity in sub-Saharan Africa. This study was conducted to examine factors that affect small-scale farmers' adoption of soil fertility management technologies in eastern Uganda, a region constrained by soil fertility. A cross-sectional survey was undertaken involving 192 small-scale farmers, with and without exposure to soil fertility management interventions. Face-to-face interviews, focused group discussion and visual observation were the data collection tools. Descriptive statistics, regression and the logit regression were used in for data analysis. The study revealed a number of soil management interventions in the region; mainly traditional in nature, and were not optimally utilised for maximum productivity. Technologies with high potential (>60%) adoption in the study area included: mixed cropping with legumes, animals manure and green manure. Technologies with low potential (>30% but <60%) adoption included intercropping with legumes, natural fallowing and crop rotation with legumes. Technologies with very low potential (<30%) included agro-forestry, use of rhizobia, inorganic fertilisers, and soil conservation. The most significant factors affecting the adoption of soil management technologies included length of interventions ( $z=4.44$ ,  $p=0.0000$ ), followed in the order of land ownership of 2 – 5 acres ( $z=3.38$ ,  $p=0.0001$ ), gender (women) of the farmer ( $z=2.66$ ,  $p=0.008$ ), land ownership over 10 acres ( $z=2.25$ ,  $p=0.0025$ ) and age of farmers ( $z=2.08$ ,  $p=0.0037$ ). Based on the observations, the entry point for research and development lies in indigenous technologies based on farmer's ranking because they fit within the socio-economic and biophysical framework.

**Key words:** Legumes, natural fallows, mixed cropping

### **Improvement of sorghum-legume intercrop productivity and economic value through light and nitrogen optimisation**

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Sorghum (*Sorghum bicolor* L. Moench), groundnut (*Arachis hypogea* L) and cowpea (*Vigna unguiculata* L) are major staple and income earning crops in eastern Uganda. They are largely intercropped, but low yields characterise their output, yet limited research has been done to ameliorate this trend. This study was deigned to improve sorghum – legume intercrop yield through optimised row arrangement and row orientation under nominal levels of N fertilisation. The study was conducted at Serere Agricultural and Animal Production Research Institute

(SAARI) in Soroti district. Improved cultivars of sorghum (*sekedo*), groundnut (red beauty, locally known as *Emoit*, and cowpea large white seeded (*Ebelat*) were used as test crops. Treatments included sorghum-legume species (groundnut and cowpea), row arrangements namely, 1:1 (alternate single row) and 2:2 (staggered double row), row orientation (N-S vs E-W), and N rate (0 and 40 kg N ha<sup>-1</sup> as urea). All intercrops were planted at the recommended spacing of 60 cm by 20 cm. The experiments were laid out in a randomized complete block design (RCBD), in a split-split arrangement. Legumes species were the main plots, N rate the sub-plots, and row orientation and arrangements the sub-sub-plots. Sorghum in the sorghum-groundnut intercrop was consistently superior to that in the sorghum-cowpea counterpart in all parameters. Staggered double rows gave better (p<0.05) sorghum, groundnut and cowpea yields and net benefit than alternate single rows. Application of N resulted in better intercrop components performance in all parameters and net benefit than no N application. The east-west row orientation resulted in a greater LAI than the N-S counterpart. Rows oriented east-west intercepted more solar radiation than their north-south counterpart in both staggered double and alternate single rows. Sorghum-groundnut permitted more light interception than sorghum-cowpea. Row orientation had no significant (p>0.05) effect on sorghum yield. Nonetheless, row arrangements 2:2 staggered double row significant (p<0.05) increased groundnut and cowpea yield. The greatest economic net benefit was obtained from groundnut intercrop in the staggered double row under 40 kg of N ha<sup>-1</sup>. The inferiority of sorghum-cowpea combination was attributed to intense competition for both above ground and edaphic resources. Intercropping sorghum-groundnut performance is more synergistic agronomically and results in greater economic returns than the sorghum – cowpea.

**Key words:** *Arachis hypogea*, groundnut, *Sorghum bicolor*

### **Physico-chemical and microbial evaluation of low-technology methods for composting urban market crop waste**

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Composting has been practiced globally for management of organic urban solid wastes. In the urban areas of Uganda, composting has not been actively practiced yet there is an increasing burden of wastes with composition of over 70% biodegradable (about 1000 t per day). Since composting has not been reasonably adopted in Uganda as a waste management technology, this study explored urban market crop wastes composting using four low-technology methods which would be applicable even on a subsistence farmer scale. The methods used were: above ground covered (AC), above ground open (AO), pit covered (PC) and pit open (PO). These methods were compared for their effects on accelerating compost maturity. Temperature in the composting waste rapidly increased reaching over 60 °C within 7 days and later reduced as composting progressed to curing phase and maturity. Similarly, pH reached highest alkalinity within 21 days and slightly declined but remained alkaline. The concentration of TOC, WSC, TN, TP, TK and NH<sub>4</sub><sup>+</sup>-N significantly (p<0.05) decreased, but increased for NO<sub>3</sub>-N. All composting methods produced mature composts within 63 days. On the basis the maturity indicators, AC method generally enhanced composting more than AO, PC and PO method but pit methods required much less investment costs and is more suitable for smallholder farmers. The polymerase chain reaction (PCR) followed by terminal restriction fragment length (T-RFLP) and pyrosequencing showed higher population diversity and abundance of bacteria

than fungi in compost from urban market crop waste compost. Principle component analysis (PCA) of the terminal restriction fragments (TRFs) showed no significant differences among the four composting methods for both fungi and bacteria. Pyrosequencing of 16S rDNA generates over 110,000 bacteria sequences of about 230 bp in length. Using these sequences, rarefaction, Chao I, cluster analysis at 3% dissimilarity showed the bacteria community diversity declined between early thermophilic and matured compost in all methods. The Shannon index ( $H'$ ) showed a decreasing diversity and increasing evenness as compost progressed from thermophilic phase to maturity for all composting methods. The most abundant phylotypes were *Proteobacteria*, *Firmicutes*, *Bacteroidetes* and *Actinobacteria*. Plant growth promoting bacteria as well as some human and plant pathogen bacteria were detected during composting even in mature compost. However, it was not clear whether the DNA was from dead or active microorganisms.

**Key words:** Bacteria, fungi, polymerase chain, temperature, thermophilic

### **Improving productivity of field pea through soil and weed management on bench terraces of South-western of Uganda**

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In Uganda, field peas is grown on the south western (SW) highlands, but yield is low, averaging barely 0.4-0.8 t ha<sup>-1</sup>, far less than 2 t ha<sup>-1</sup> attained in other countries like Russia. Soil nutrient depletion is reportedly high from the bench-terraces, and all these could in totality be influencing the overall productivity. This study was designed to establish limiting nutrients to pea productivity, and also evaluate the impact of improved soil and weed management (SMW) practices on field pea productivity in SW Uganda. Nutrient studies included addition of 25 kg N ha<sup>-1</sup>, 60 kg P ha<sup>-1</sup>, and 60 kg K ha<sup>-1</sup>, applied singly or in combinations. For the SWM, treatments included; rough and fine tillage; weeding at 30 days after planting (DAP) and no-weeding; no fertiliser and N, P, K fertiliser combination applied at 25, 60 and 60 kg ha<sup>-1</sup> respectively. For both studies, treatments were applied interactively in a factorial arrangement on the upper part (UPT) and lower part of terrace (LPT). Phosphorus gave the highest increment ( $p < 0.05$ ) in nodule number (53.8%) and dry weight (65.7%). All nutrient combinations with phosphorus resulted in significantly ( $p < 0.05$ ) high nodule number and weight. At flowering, single nitrogen application gave the highest above-ground dry matter (4932 kg ha<sup>-1</sup>), which was 39% higher than the control. At harvest, a combination of nitrogen and K gave the highest dry grain yield (911 kg ha<sup>-1</sup>). These results indicate that while P was crucial for nodule production and function, the nitrogen fixed through the biological process was not sufficient to cover the needs of the crop, and N was still most limiting for pea production. Weed density was not significantly ( $p > 0.05$ ) influenced by tillage treatments. Rough tillage with fertiliser addition significantly ( $p < 0.05$ ) increased nodule dry weight. Rough tillage significantly ( $p < 0.05$ ) influenced above-ground dry matter at flowering in UPT, but not in the LPT, where rough tillage plus no weeding resulted in the highest stover yield. Fine tillage, weeding and fertiliser application significantly ( $p < 0.05$ ) increased grain yield in UPT by as much as 47% over the control. Weeding was crucial in UPT under fine seedbed but not in a rough tilled plot in LPT where the pea plants were more vegetative and susceptible to lodging without the support of

weeds. The highest average grain yield obtained in this study was 911 kg ha<sup>-1</sup>, still lower than yields obtained elsewhere.

**Key words:** Dry matter, fertilisation, nodules, tillage, weeding

### **Water balance of agricultural catchment at Oimai-Wera in the Lake Kyoga Basin, Uganda**

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Water is one of the major factors limiting agricultural production in the Lake Kyoga Basin (LKB) in Uganda. This region faces a moisture deficit yet rainfall received is relatively enough for crop production. A water balance study as a tool in land management was carried out in Oimai-Wera Village, Katakwi District, in Uganda to quantify the water balance subprocesses (inflows and outflows) resulting from a known amount of rainfall. The objective was to improve our understanding of the nature of the soil moisture deficit problem in the Oimai-Wera, Lake Kyoga Basin. Seven meteorological models were also calibrated and the best fit experiment site was divided into 3 strata (summit, back slope and foot slope) and soil characterisation carried out for each. Three run-offs plots, each measuring 15 m by and 10 m and separated by 2 m were randomly located on each landscape position. Meteorological data were collected from the Automatic Weather Station (AWS) and soil moisture content measured using A Time Domain Reflectometry (TDR). Rainfall received over the wet period of the study was mostly generated by rainfall greater than 20 mm. Run-off was highest at the back slope and lowest at the summit and foot slope (19.4, 10.8 and 9 mm, respectively). On aggregate, 93.2% of the soil water loss occurred as evapotranspiration (ET) across all landscape positions. Run-off contributed 3.86% of the soil water lost. A total of 8.3% was stored in the root zone (error in the calculation was of about 5%). Subsurface flow was insignificant. Soil moisture down the soil profile varied significantly across seasons, landscape position and soil depth ( $p < 0.05$ ). The best fit meteorological models were; Hargreaves which gave the best estimate with an underestimation of 9.6%, followed, Abtew (19%), FAO (1998) Penman-Monteith (20.7%) Priestley and Taylor (20.9%), Romaneko (26.2%). The best fit meteorological models were Hargreaves which gave the best estimate with an underestimation of 9.6%, followed by, Abtew(19%), FAO (1998) Penman-Monteith (20.2%), Makkik( 20.7%) Priestley and Taylor (20.9%), Romaneko (26.2%) and lastly Penman 1948 (34.3%). Evaporanspiration constituted a major water loss in the LKB cropping system and the best fit meteorological model was Hargreaves.

**Key words:** Evapotranspiration, moisture deficit, run-off

### **Biophysical and crop management gradients driving within farm variability of highland banana yields in Butare Valley in Uganda**

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Large within and between farm variability of banana (*Musa* spp.) yields in Uganda are caused by a complex of soil fertility differences, pests and light availability. These biophysical factors

are again influenced by crop management practices, which show large spatial variability. The objective of this study was to quantify the relative contributions of soil fertility factor, pests and diseases and crop management practices to banana yield losses within and between farms in Ntungamo district South-western Uganda. Ten farms representing a gradation of biophysical (slope position) and socioeconomic (wealth status) variability were selected for the on-farm monitoring of plant performance in Butare subcounty. On each farm, 15 mats of the most dominant genotype (cv.Enyeru) were selected for the study along a transect parallel to the slope such that they fell within a range of relative distances (RD), close, mid and remote from the homestead. Boundary-line analysis revealed that soil fertility factors collectively contributed to 60% yield limitations, pests accounted for 30.0% and crop management 10.0%. Among the limiting factors, banana weevil (*Cosmopolites sordidus* (Germar)) accounted for the highest (26.7%) limitation, soil K/Mg ratio (20.0%), soil pH (16.7%), excessive leaf pruning (10.0%), Ca K-1+Mg+Ca and nematodes each 3.3%. Banana streak virus, black Sigatoka and leaf spots depressed bunch weights by 21.6, 28 and 19 kg, respectively in severely infested plants compared to disease-free ones. pH and inadequate Ca limited yield improvements only among poor farmers as opposed to high weevil pressure among medium and rich farmers. The former had nematodes as an additional constraint and high soil K/Mg<sup>-1</sup> ratio, which also occurred among resource rich farmers. Mat spacing was significantly ( $p < 0.05$ ,  $R^2 = 0.904$ ) negatively correlated with bunch weight, and the heaviest bunch occurred at 2.6 m x 2.6 m (1512 mats ha<sup>-1</sup>) compared to the recommended 3.0 m x 3.0 m. However, the poor farmers who had significantly ( $p < 0.001$ ) higher plant densities than wealthier ones indicated, proper spacing should be a greater concern among poorer farms. Number of functional leaves.

**Key words:** Diagnostic survey, relative distance, spatial variability

### **Validation of a GIS-USLE Model in a banana based micro-catchment of the Lake Victoria basin**

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Soil erosion is a wide spread phenomenon in Uganda's Lake Victoria basin (LVB) and is thought to be one of the major causal factors of the declining yield of banana in the basin. Choice of appropriate conservation practices depends on accurate quantification of the magnitude of damage. Variability across a toposequence on the catchment level makes assessment studies technically difficult and economically not feasible. A GIS based Universal Soil Loss Model was initialised and used in this study to: (i) validate the predictive capacity of the initialised GIS-USLE model across the major land uses and soil types in the micro-catchment; and (ii) quantify the on-site damage in terms of soil loss, soil structure deterioration and nutrient loss. Run-off plot (15 m x 10 m) approach was used to collect runoff and sediment for soil and nutrient loss quantification from different land uses. Soil structure was assessed before and after the two rain seasons. USLE parameters were obtained from: mean annual rainfall-R factor, soils map-K factor, Topomap-LS factor, aerial photographs and satellite images-C factor using modelling operations in ILWIS computer package. Soil loss varied ( $p < 0.05$ ) across the different land use types with the highest soil loss observed in annuals at 71 t ha<sup>-1</sup> and the least in rangeland at 3.2 t ha<sup>-1</sup>. Similarly, nutrient loss significantly differed ( $p < 0.05$ ) across land uses with banana posting the highest nutrient losses. Soil loss varied ranging from 2-25%. It was also closely related to soil structure damage ( $r = 0.62$ ). Applicability of the GIS-based USLE was demonstrated

but needs to be calibrated. Land use had stronger influence on soil loss than slope. Up to 50 t ha<sup>-1</sup> yr<sup>-1</sup> of soil was predicted to be lost from slopes of 8-25% gradient, with area coverage of 41%. The study findings indicate that land use and surface cover characteristics are strategic in soil erosion control in the area.

**Key words:** Matooke decline, nutrient loss, run-off, sediment

### **Nitrogen and phosphorus fertiliser application for increased growth and grain yield of maize**

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Maize (*Zea mays* L.) production ranks second among cereal production world-wide, with an average yield of 4.0 t ha<sup>-1</sup>. While maize has attained prominence in Uganda, its average yield of 1.5 t ha<sup>-1</sup> is low in spite of the use of high yielding and pest resistant varieties. The problem is probably attributed to low nutrient status of most Uganda soils. Thus, two field trials were conducted at Makerere University Agricultural Research Institute, Kabanyolo to determine the effect of nitrogen and phosphorus on the growth and yield of maize, variety Longe 1. Nitrogen was applied at 0, 40, 80, 120 and 160 kg N ha<sup>-1</sup> as urea while phosphorus was supplied at 0, 50, 100 and 150 kg P ha<sup>-1</sup> as triple Super Phosphate. Visually, plants which received nitrogen were robust, healthier and greener compared to the control plots. There was a linear regression between most parameters and fertiliser application. Grain yield increased from 3.4 t ha<sup>-1</sup> in the control to 10.741 t ha<sup>-1</sup> when N and P were applied.

**Key words:** Triple super phosphate, urea

### **Influence of nitrogen and sulphur rates on amino acids of sorghum and maize**

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The influence of different fertiliser levels of N and S on the amino acids of sorghum (MUS 16) and maize (Katumani) was studied in Uganda. For the nutritional reasons, sulphur amino acids were of particular interest. Field experiments were carried out for both sorghum and corn and a greenhouse experiment for sorghum only. Data from the greenhouse experiment showed an appreciable increase in the utilisation of N at high N fertiliser level as S level was increased. The increase in the utilisation of N resulted in an increase in amino acid N/protein S ratio, i.e., a decrease in protein quality with reference to sulphur amino acids. The absolute sulphur amino acid content, however, did increase. Adequate consideration of S fertilisers for soils deficient in S but amply supplied with N is suggested.

**Key words:** Amino acids, nitrogen utilisation, protein quality

### **Soil quality indexing and mapping: Evaluation of a GIS- based tool on a Lake Victoria Basin microcatchment Ferralsol**

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The concept of soil quality is particularly crucial given the high rates of soil degradation prevalent in Uganda. There is need for a soil system-oriented or holistic soil quality index for detecting and monitoring soil degradation, and evaluating the impact of management interventions, to bolster decision-making in soil degradation management. The objective of this study was to evaluate the reliability of kriging at field level indexing and mapping of soil quality for agricultural production on a Ferralsol in the Lake Victoria Basin of Uganda. The study was carried out at Makerere University using a survey approach on 1.2 ha (120 m x 100 m) field. The field was selected such that one half of it lay in an area under annual cropping and the other half under perennial cropping over the past 5 years. A grid of points was established over the field at intervals of 20 m between and within rows. At each grid point, a georeferenced soil sample was taken from the depth 0-20 cm and analysed for various parameters. Although total N, and exchangeable K had weak spatial correlation, unlike available P and OC, all the soil quality indicators were accurately estimated by both ordinary and indicator quality kriging. There was no significant ( $p < 0.05$ ) difference between predicted and observed values for each soil quality indicator. The spatial distribution of soil quality followed the same pattern as the land use in the field; the soil quality being poorer in the annual crop (maize-fallow rotation) area but richer in the perennial (banana) crop area.

**Key words:** Decision-making, land evaluation, land use, prediction

### **Factors influencing soil and water conservation practices in a banana based system of the Lake Victoria Basin in Uganda**

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Most studies on soil and water conservation concentrate on either the biophysical or socioeconomic factors but hardly on their interactive effects. This study undertook a simultaneous characterisation of the biophysical and socioeconomic aspects within a small microcatchment of the Lake Victoria Basin in Uganda. The characterisation of the biophysical factors was made both within a selected 4 km long transect and at the household level. Three villages (Kasanje, Kanabukuliro and Nabinene) in Bukoto County, Masaka district were covered. A total of 50 farmer respondents participated in the household survey. It was clear from the study that mulching and soil bunding were the two major conservation practices. Eighty per cent and 50% of the farmers practiced mulching and soil bunding, respectively. The distribution of these SWC practices across cropping systems was not uniform. Thus, both mulching and soil bunding were concentrated mostly in the banana cropping system. Agroforestry was practiced but mostly for providing shade in coffee fields. The three main socioeconomic constraints directly influencing the use and adoption of indigenous and introduced SWC technology

were, lack of capital for investment (55.6%), lack of information (ignorance) of the soil bunding technique (36%) and scarcity of labour (36%).

**Key words:** Agro-forestry, mulching, socio-economic constraints, soil bunding

### **Effect of three organic residues on nitrogen uptake and dry matter yield of rhodes grass**

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Crop growth and productivity in Uganda is currently affected by low soil fertility. This has serious implications to food accessibility by the population, and is predicted to get worse, given the high rate of population increase in the country. As such, cheap sources of soil nutrients will go a long way to improve the production of the soil and increase crop yields. A green house experiment was conducted at Kabanyolo farm in Uganda to evaluate the effect of three organic residues on nitrogen uptake and dry matter yield of Rhodes grass. The residues used were leaves and twigs of *Leucaena* and *Cassia*, and banana leaves. *Leucaena* and *Cassia* residues were applied at rates of 25, 50 and 100 kg N ha<sup>-1</sup>. Banana leaves were applied at 50 kg N ha<sup>-1</sup>. Rhodes grass was cut at the growth after 45, 90 and 135 days. No significant response to residue treatments was obtained at 45 days but at 90 and 135 days. However, N uptake and dry matter yield were significantly increased. The greatest response was obtained when *Leucaena* residues were used at all the three rates. The 100 kg N ha<sup>-1</sup> rate gave the highest response for all the three residues. The results suggest that farmers who seek to improve crop growth can effectively use the three residues if they can afford the high levels and if the crops have a growth and nutrient uptake period of more than 45 days.

**Key words:** Banana, *Cassia*, C:N ratio, *Leucaena*

### **Quantification of evaporation in a sorghum crop in Oimai- Wera Katakwi District in Uganda**

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Quantification of evapotranspiration is key to water management for improved crop production. This study was carried out to investigate the major soil moisture constraints experienced by crops in Katakwi district; a dry- land region in north eastern Uganda. Evapotranspiration was quantified directly and indirectly using the modified lysimeter and the Bowen ratio-Energy balance (BREB) methods, respectively. Daily rainfall records were taken using both an automatic weather station and simple rain gauges. Evaporation was determined by desegregation of evapotranspiration using transpiration values derived from a pot experiment. Variability of ET at three landscape positions (summit, mid-slope and foot-slope) was determined using the BREB method. A trial was set up at each of the land scape positions with a hypothesis that pan evaporation is a good measure of potential evapotranspiration (PET) tested using data of water loss through evaporation from a saturated soil and free water. Results showed that ET constitutes a significant portion (over 60%) of the loss of the rainfall received throughout all

the considered stages of sorghum growth in both seasons of the year with the vegetative stage of the second season being the only exception. The ratio of evaporation/ET was greater than 0.5 during the establishment stage for both seasons. That for the vegetative and the flowering stages was greater than 0.5 in the first season and less than 0.5 in the second season. However, in all the growth stages, soil water loss through evaporation from under the crop was significant enough to warrant the establishment of control measures. ET did not vary across the landscape positions considered. For the study site, estimation of ET using a saturated sandy loam soil was superior to the conventional pan evaporimeter. Also, the soil moisture constraint was predominantly through water loss by evaporation and uneven rainfall distribution.

**Key words:** Eaportanspiration, rainfall, soil moisture

### **Effect of potassium and nitrogen on true potato seed production and quality**

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True potato seed (TPS) is one of the best alternative planting materials to the traditional seed tubers especially in the lower altitude areas (<1500 meters above sea level) that are highly plagued by diseases. The performance of TPS depends on a number of factors including the nutrition of the mother plants. Two field studies and one greenhouse experiment were conducted to evaluate the response of “true potato seed mother plants to potassium and nitrogen in several potato (*Solanum tuberosum* L.) genotypes, namely Victoria, Kisoro, CIP 381403.1. The study was conducted at field; Namulonge Agricultural and Animal Producton Research Institute (NAARI) low altitude 1150 masl ) and at Kalengyere Research Station ( high altitude 2450 masl). In the first field experiment, K and N were applied jointly at rates of 0, 132.8 and 265.6 kg ha<sup>-1</sup> and 0, 120 and 240 kg ha<sup>-1</sup>, respectively. Flowering varied significantly among potato genotype ranging from total flower abscission to as high as 164 flowers per plant. Some genotypes had more flowers at Kalengyere, while others performed better at NAARI. Potassium application increased flowering by 50% and reduced set by 44% during 1995 short and long rains, respectively. *In- Vitro* pollen germinability and pollen production increased by 26.8 to 35.4% and 42.8 to 52%, respectively due to K application and true potato seed weight( 100-seed) by 30-42%. High K application rate (265.6 kg ha<sup>-1</sup>) generally depressed dry matter yield and reduced TPS weight by 3.5-16%. Potassium and N interaction affected TPS weight and berry yield. High rates of K impaired the uptake of Ca and Mg by potato mother plants and suppressed flowering, berry set and TPS weight. Leaves had the greatest N concentration, which was the highest in variety Kisoro (93.3 g kg<sup>-1</sup>) and the least in CIP 800212 (66.3 g kg<sup>-1</sup>) with a mean of 81 g kg<sup>-1</sup>. Stems on the other hand had the least N concentration. Berries had the greatest P concentration; followed by leaves tubers and lastly stems. Potassium was fairly distributed among plant parts, but was in greatest concentration in stems (38% of total K in plant parts), followed by the leaves (28.3%), tubers (20.2%) and then berries (13.5%). Mother plants supplied with K and N at the rates of 132.8 and 120 kg ha<sup>-1</sup>, respectively, produced true seed with high seedling emergence and vigour comparable to that of the imported TPS progenies. Nitrogen significantly ( $p \leq 0.05$ ) increased seedling vigour (by 46% over the control seedlings). However, there was a negative interaction between K and N on seedling emergence and

vigour, and K rates higher than 132.8 kg ha<sup>-1</sup> depressed these parameters by 24.2 and 48%, respectively.

**Key words:** Abscission, flowering, germinability, seedling vigour

### **Agronomic and economic value of cover crops and minimum tillage integration in a maize-bean production system in Uganda**

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Maize (*Zea mays* L.) and common bean (*Phaseolus vulgaris* L.) are important staples and cash crops in sub-Saharan Africa. They are typically grown as intercrops or in rotation systems, but their yields are very low due to soil fertility decline. This study was designed to improve soil fertility through agronomically and economically rationalised integration of leguminous cover crops and minimum tillage in maize-bean cropping systems in Uganda. Two studies were conducted, namely a socio-economic survey in Pallisa and Mbale district, and a field experiment in Central Uganda, Pallisa and Mbale districts. Treatments for the experiment included minimum tillage (herbicide application or slash). Other treatments included; mucuna (*Mucuna pruriens*), lablab (*Lablab purpureus*), canavalia (*Canavalia ensiformis*), crotalaria (*Crotalaria paulina*), and natural fallow. The survey showed that mucuna and lablab were the most preferred cover crops, while crotalaria was the least used. In Pallisa, cover crops were planted as boundary hedges and used for fodder, while in Mbale; they were intercropped with banana to control erosion. Overall, canavalia performed best in dry matter accumulation (6.2 t ha<sup>-1</sup>), while the natural fallow was highly inferior (2.1 t ha<sup>-1</sup>). Kawanda (Central Uganda) and Pallisa sites, canavalia dry matter was greater than natural fallow by 2.3 and 6.9 t ha<sup>-1</sup>, respectively. In Mbale, canavalia out-yielded lablab which performed poorest by 59% yield at Kawanda was the highest (5.0 t ha<sup>-1</sup>) and the lowest at Pallisa (3.1 t ha<sup>-1</sup>). Maize yield in herbicide applied plots (4.8 t ha<sup>-1</sup>) was greater than that of slash (3.7 t ha<sup>-1</sup>). At Mbale, maize yield in mucuna increased as much as 27% over the poorest performer (natural fallow), while for Kawanda and Pallisa sites, yield was not significantly different among cover crop species. Bean yield at Mbale site (0.44 t ha<sup>-1</sup>) was significantly higher than that of Kawanda (0.36 t ha<sup>-1</sup>). Herbicide out-yielded slash by 24% for both Pallisa and Kawanda. On cover crop basis, bean yield in lablab fallow in Mbale was 50% greater than that of the lowest yielder (canavalia) while at Kawanda, canavalia was 43% higher than that of mucuna. Maize and bean net benefits from herbicide applied plots were greater than that of slash for the three study sites.

**Key words:** *Lablab purpureus*, *Mucuna pruriens*, *Phaseolus vulgaris*

### **Influence of phosphorus resources on soil phosphorus dynamics and crop productivity in Rwanda**

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Biomass transfer is considered a potential technology to overcome soil fertility depletion for food security in sub-Saharan Africa. In East Africa, soil fertility and crop production rely on

organic resources but phosphorus constitutes a major limiting nutrient to crop production in many soils due to low P content in most organic materials, low soil P availability and high P-fixing capacity. This study focused on characterisation of organic P sources and understanding the effects of plant quality on soil chemical and biological properties, which in turn influence P dynamics, soil quality index and maize yields as are important and this focus of this study. Experiments were undertaken at Rubona in southern Rwanda with treatments: limestone at 2.5 t ha<sup>-1</sup>, TSP at 25 kg P ha<sup>-1</sup> and 50 kg P ha<sup>-1</sup>, respectively; and Calliandra, Tithonia and Tephrosia at 25 kg P ha<sup>-1</sup> and 50 kg P ha<sup>-1</sup>, respectively. Results of the incubation study showed that the combination of organic with inorganic P sources did not improve C and P mineralisation compared to organic P sources applied independently. Plant quality parameters such as initial total P, N, C: P, C: N: P ratios were the best predictors of P mineralisation while total N content predicted C mineralisation. Seasonal application of organic P sources, inorganic P and their combination decreased exchangeable acidity and aluminium in the input and residual phases. In acid soils, organic P sources can substitute lime to decrease exchangeable aluminium toxicity, P adsorption maximum and adsorption affinity constant. Tithonia combined with TSP at high P level had the greatest effect on both maximum and affinity constant in the input phase, while Tephrosia combined with TSP at high P level had greater effect in the residual phase. Organic materials applied indigently or combined with TSP at low P level had least effect on adsorption affinity constant. In the input phase, only application of organic materials combined with TSP at high P level improved soil carbon relative to the control. Organic inputs applied independently appeared to raise acid phosphates activity but for the most part the effect was not significant except Tithonia 25P that was applied independently. Application of cumulative P of 200 kg P ha<sup>-1</sup> from combination of Tithonia with TSP at high P level inhibited APA. Lime, organic materials applied independently and combined with TSP increased systemically microbial biomass carbon (MBC) in the input phase. In the residual phase, all treatments were superior to control except TSP at low P level. Most of the treatments with Tithonia and the combination of Tephrosia with TSP at high P level improved microbial biomass phosphorus (MBP) in the input phase while in the residual phase only Tithonia combined with TSP at high P level improved MBP.

**Key words:** Biomass, Calliandra, P availability, Tephrosia, Tithonia

### **Performance of neochetina weevils on water hyacinth in lake Victoria Basin river systems in Tanzania**

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Water hyacinth (*Eichhornia crassipes* (Martius) Solms-laubach), is the most obnoxious aquatic weed known worldwide. Biological control using *Neochetina* weevils was initiated in Tanzania in 1995; however this control mechanism was successful in Lake Victoria where water hyacinth was reduced by 80%, but failed in some water bodies. Studies were conducted to evaluate potential effect of nitrogen, phosphorus and silt on weevil at Kyaka near Kagera River in Kagera region, Tanzania. Kagera river was found to have the highest water hyacinth densities (44.2 plants m<sup>-2</sup>), followed by Mara (32.8 plants m<sup>-2</sup>), Pangani (27.2 plants m<sup>-2</sup>) and the least in Sigi (22.8 plants m<sup>-2</sup>). Plant height was highest in Mara (51.04 cm), followed by Kagera, Pangani and the lowest in Sigi (28.6). Other plant parameters namely, leaf length and width and root length followed the same trend. Kagera river had the highest number of ramets per plant (1.13), followed by Mara, Sigi and Pangani (0.69). The number of adult weevils feeding scars per plant

was highest in Pangani (22.1) and Sigi (17.81). Water hyacinth growth suppression and population reduction was only evident in Pangani and Sigi rivers. On the other hand, the weed continued to proliferate in Kagera and Mara rivers in Lake Victoria basin despite monthly weevil releases. Weevil damage was suppressed at higher N (100 mg N L<sup>-1</sup>), but not high P application rates. Plants fed with high levels of N had low counts of adult weevils and pupae. On the other hand, growth of water hyacinth was limited in low N by 40%, yet weevil numbers, eggs, larvae and pupae per plant as well as weevil damage, increased at low N. Similarly, the number of adult weevil feeding scars per plant was higher ( $P < 0.01$ ) in lower N than at high levels. Electrical conductivity was highest in Kagera (969.8  $\mu\text{scm}^{-1}$ ) followed by Mara; while Pangani and Sigi had the lowest. Water temperature was high in Pangani (30.39 °C) and Sigi (24.9 °C), while Mara had (26.2 °C) and Kagera had the lowest (26.23 °C).

**Key words:** Biological control, *Eichornia crassipes*, nitrogen

### **Development of nutrient management strategies along a continuum of dairy production intensification in Uganda**

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Soil fertility decline is a leading form of land productivity degradation in Sub-Saharan Africa. Colossal quantities of nutrients are removed annually from soils, especially through crop harvests, unreciprocated by nutrient inputs. A study was conducted to: (i) establish farm categories on the basis of dairy intensification in Uganda for targeting nutrient management interventions; (ii) evaluate the effect of dairy intensification on major plant nutrient balances as a mechanism for identifying entry-points for intervention and subsequent contribution to sustainable productivity of dairy production systems; (iii) identify indicators of nutrient status for assessment of dairy production systems; and (iv) identify options for improving nutrient balances at various levels of intensification of dairy production in Uganda. The study was conducted in the districts of Jinja, Masaka and Mbarara in Uganda in two parts, namely (i) a cross-sectional characterisation of dairy systems; and (ii) a longitudinal study of nutrient flows and their management. From this study, 4 major dairy categories were identified, namely, Herding (HD), Tethering (TE), Fenced (FE) and Zero grazing (ZG), in order of increasing intensification of production. The largest nutrient influxes into the Farms were those in to the ZG category and least into FE. Off-farm feeds were responsible for the large nutrient influxes into the farms and in the case of N, biological N fixation made a substantial contribution. Nutrient inflows to the farms through direct applications from the off-farm were negligible in all categories. The major channel for N, P and K outflows from the Farms was through crop harvests, with the largest values in the ZG category, and lowest in HD. Dairy intensification, to an extent, had a positive effect on Farm N, P and K balances, but the contrary was true for land balances. With respect to Farm Nutrient balance sheets, ZG category had the largest positive N, P and K values. On the other hand, the FE presented the poorest scenario, with all consistently negative net balances.

**Key words:** Nitrogen fixation, nutrient balances, zero-grazing

### **Impact of refugee settlement on forests and agricultural land resources in Moyo District, Uganda**

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Moyo district is a small populated area in the West Nile region in Uganda that has been hit by an influx of refugees escaping a two-decade war between the Government of Sudan and the rebel group Sudan Peoples' Liberation Army in Southernthern Sudan. Despite a contingency plan put in place by the local authorities and the UN agencies such as UNHCR and WFP, the Itula sub-county, where the refugees have been settled since 1987, is actually part of the gazetted Forest reserve, Madi Controlled Hunting area and the Wetlands of the Albert Nile. This settlement has had an impact on natural resources in this reserve. The objective of this study was to determine the impact of refugee settlement on forestry and agricultural land resources. A sample of 200 respondents was drawn from the refugee community while 50 were from host communities. Interviews, questionnaires and focus groups were used as data collection techniques to obtain information. It was clear that a number of activities undertaken by the refugees had immense pressure on the environment, and that Era forest reserve and agricultural land resources have been degraded. Despite numerous efforts by NGOs and the local leadership to promote environmental conservation, the capacity of the organisations and the local government to address environmental concerns of such magnitude is still insufficient. Priority should be given to addressing environmental concerns, availing information, effective planning and integration of environmental concerns in all development programmes.

**Key words:** Albert Nile, environment, Era forest reserve

### **Community initiatives in improving urban environment in Eastern Uganda**

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Building strong partnerships with the community can enhance development and environmental conservation. The purpose of the study was to establish persistent environmental concerns and to understand how the community is addressing them in Masese, Jinja, Uganda. A qualitative approach using questionnaires, interviews, FGDs and PRA tools to gather primary data was adopted. Relevant literature was reviewed for secondary data. The study revealed that solid wastes, diseases and poverty were still persistent environmental issues in the community. The three main concerns are linked. The solid wastes enhance disease, while poverty deters community initiatives in managing environmental recovery. It was noted that poverty may not be the ultimate root cause of environmental degradation weakness within partnerships in the community play a big role. Due to the nature of organisational structures of the groups, heterogeneity within the community, land tenureship and transient nature of these communities, partnerships were weak.

**Key words:** Land tenure, poverty, solid wastes, partnerships

### **Fish farming as an enterprise in western Uganda**

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Fish farming is one of the upcoming farming systems in Uganda most prominent in the northern and western parts of Uganda, though it has remained at subsistence level. A lot of research has been carried out on fish farming in general, little is determined about the viability and suitability of this farming system. This study aimed at identifying the best-bet practices and critical factors limiting farmed fish production. A survey households which practised fish farming in the districts of Bushenyi and Kasese in western Uganda was conducted. Results indicated that major activities in fish farming include pond construction, feeding, fertilising, clearing the pond area and harvesting. Pond construction was the most costly activity, while other activities were mainly carried out by the household members. At a 10% increment in quantity of fish fry, a 4% increment in prices of mature fish and fish fry and a 4% increment in variable costs, the project was assumed to break even at the end of the second season (in twelve months). The results still revealed that 62% (289,651 km<sup>2</sup>) of the study area was suitable for fish farming in terms of soil, terrain and water loss. Predation was the most recorded problem; however silting was reported to cost the fish farm enterprise dearly at 16.9% of total costs.

**Key words:** Fish ponds, fish predation, fry, silting

### **Procedures for gazettement wetlands in Uganda: A case study of Nakivubo wetland in Kampala District**

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Nakivubo wetland forms part of the wetland system of Inner Murchison Bay in Kampala District in Uganda. The pressure of increasing population, and the resulting expansion of agriculture, and industrial and urban development have caused significant destruction of Nakivubo wetland thereby impacting on the water quality of the bay. In order to curb further destruction and loss of the wetland, gazettement is under way and this requires reliable information on boundary delineation to support decision-making. In an attempt to provide solutions to the problem, GIS was employed to establish the best boundary for gazettement Nakivubo wetland within the framework of the law. The regulations on Wetlands, Riverbanks and Lake shores (2000) were examined to provide a framework in which gazettement should be undertaken. Consultations were also made with key agencies concerned with gazettement of Nakivubo and establishment of the best option for the boundary delineation. Literature was reviewed to enhance baseline information. It was noted that the procedure for the gazettement as stipulated in the Regulations was generally not followed by key stakeholders with over 70% roles not fulfilled. Despite this short-coming the gazettement of Nakivubo wetland proceeded with new procedures being introduced. Boundary demarcation was noted as key in the procedure for gazettement of Nakivubo wetland and using GIS established the best choice as GPS ranked highest against the contour and ecological criteria. Application of GIS was valuable for decision-making in this case boundary delineation and the related implications. Thus GIS was a useful

tool that provided an innovative way of integrating, analysing and presenting information for decision on the best choice.

**Key words:** GIS, GPS, Lake shores, Murchison Bay

### **Impact of agricultural activities on the pattern and spread of altered Mabira forest habitats in Uganda**

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Millions of hectares of forest habitats around the world are converted into agricultural fields annually. In Uganda, forest habitats are lost at a rate of 7% per *annum*. At this rate, it is predicted that there will be no biomass outside forest reserves by 2025. This study was carried out to assess the impact of agricultural land use on the pattern and spread of altered forest habitats in Mabira forest reserve, Uganda. Participatory Rural Appraisal (PRA) methods, interviews, observation, line transects and questionnaires were the main instruments in data collection. It was concluded that agricultural land use is associated with the habitat alteration that was observed as boundary and linear processes as well as hotspots. It was recommended that further forest conservation requires environmental education, increased mapping and monitoring as well as restoration of degraded areas so as to ensure forest conservation.

**Key words:** Forest biomass, habitat alteration

## **Moi University, Kenya**

## Root distribution and inorganic nitrogen in an Alfisol under different cropping systems

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Nitrate can accumulate in the subsoil under continuous cropping with little or no nutrient inputs. In order to effectively utilise this subsoil nitrate, deep rooted plants are required in the cropping system. Tree fallows may have potential to capture subsoil nitrate, pump it to the topsoil and recycle the N through leaf litter. This study was conducted on a Kandic Paleustalf soil at Machakos district in eastern Kenya, to compare subsoil nitrate and rooting in four land use systems (LUS): natural weed fallow, bare fallow, *Sesbania sesban* fallow and continuous maize. The results showed that nitrate in the top 30 cm for the four LUS ranged from 6.9 to 11 kg N ha<sup>-1</sup>. Nitrate in the bare fallow increased to 14 kg N ha<sup>-1</sup> at 30-50 cm and 86 kg N ha<sup>-1</sup> at 50-100 cm. Nitrate at 50-100 cm was the next highest in continuous maize (28 kg N ha<sup>-1</sup>). *Sesbania sesban* and weed fallows had lower amounts of 9.7 and 5.0 kg N ha<sup>-1</sup>, respectively, at 50-100 cm. Nitrate up to 150 cm depth in maize was 54 kg N ha<sup>-1</sup> of which 42 kg N ha<sup>-1</sup> was at 75-150 cm. Weeds fallow had 44 kg nitrate-N ha<sup>-1</sup> up to 150 cm depth, of which 31 kg N ha<sup>-1</sup> was at 75-150 cm. *Sesbania sesban* had 25 kg nitrate-N ha<sup>-1</sup> up to 150 cm depth, of which 10 kg N ha<sup>-1</sup> was at 75-150 cm. Root length density in the topsoil (0-30 cm) was higher for the weed fallow (96,000 km ha<sup>-1</sup>) than maize (17,900 km ha<sup>-1</sup>) and *Sesbania sesban* (47,500 km ha<sup>-1</sup>). Total root length up to 60-cm depth was 28,560 km ha<sup>-1</sup> for maize, 113,200 km ha<sup>-1</sup> for weeds and 60,750 km ha<sup>-1</sup> for *Sesbania sesban*. The root length at 60-150 cm as a percentage of the total to 150 cm was 39% for maize, 22% for weeds and 26% for *Sesbania sesban*. *Sesbania sesban* had an additional root length density of 28,050 km ha<sup>-1</sup> at 150-285 cm, which comprised 25% of its total root length to 285 cm. Subsoil nitrate was inversely related to root length density for all LUS. *Sesbania sesban* fallow had larger dry biomass of roots retained on a 500 micron sieve than weed fallow and unfertilised maize. Root biomass up to 150 cm was 10.9 tonnes ha<sup>-1</sup> in *Sesbania sesban*, 0.91 tonnes ha<sup>-1</sup> in weeds, and 0.78 tonnes ha<sup>-1</sup> in maize. In addition, *Sesbania sesban* had 0.75 tonnes ha<sup>-1</sup> at 150-285 cm, which comprised 6.5% of its total root biomass. Aboveground: belowground biomass ratios were 2.5 for *Sesbania sesban*, 16 for maize and 5.8 for weeds. The nutrient contents in total aboveground biomass were 85 kg N ha<sup>-1</sup> and 7 kg P ha<sup>-1</sup> in maize, 50 kg N ha<sup>-1</sup> and 7 kg P ha<sup>-1</sup> in weeds, 248 kg N ha<sup>-1</sup> and 11 kg P ha<sup>-1</sup> in *Sesbania sesban*. Presence of root in the subsoil and the continuous presence of growing plants in *Sesbania sesban* and weed fallows as compared to continuous maize, reduced subsoil nitrate. Therefore, it is clear that incorporating deep rooting fallow system into the cropping system can substantially reduce subsoil nitrate. The contribution of *Sesbania sesban* from its leaf litter to soil nitrogen would be greater than the contribution from weed biomass and maize stover.

**Key words:** Kenya, nitrate, *Sesbania sesban*, sub-soil

## **Chemical properties of soils under natural and plantation forests in Kakamega Forest, Kenya**

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Some physical and chemical properties of soils under different forest vegetation types were evaluated in Kakamega forest, Kenya. A total of 12 sampling plots, measuring 25 m<sup>2</sup> in three sites were studied up to depth of 200 cm. Significant changes were observed in some physical and chemical properties, especially in the top 30 cm. Below this depth, no significant differences were observed among the different vegetation types. Most significant changes were recorded for those properties that are highly correlated to soil organic matter. Bulk density, aggregate stability and moisture content were significantly different between soils under natural forests and those under plantation forests and grasslands ( $p < 0.05$ ). However, reforestation of the site with plantation forestry did not change the soil texture. Organic C, total N, available P, pH and exchangeable  $K^+$  and  $Na^+$ , declined significantly in the upper 30 cm of the soils under exotic tree plantations and grasslands, but not with *Maesopsis*, when compared to natural forests. Exchangeable  $Ca^{2+}$ ,  $Mg^{2+}$  and effective CEC did not differ significantly in soils under the different vegetation types. Carbon to N ratio and exchangeable acidity did not show significant differences among the various vegetation types. Some significant changes in soil physical and chemical properties occurred following the conversion of native natural tropical forest with consequent replacement with plantation species especially exotic.

**Key words:** Carbon, CEC, nitrogen, phosphorus, pH

## **Effects of phosphorus and nitrogen on grain yield of common beans cultivar “Rose coco”**

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Common bean (*Phaseolus vulgaris* L.) is an important staple food worldwide and more important in developing countries because it is the cheapest source of protein. Production of common bean in Kenya is declining, while the demand is increasing. The decline in production is partly attributed to the declining soil fertility and non replenishments of nutrients in production of the crop. A field study in the Rift Valley Province, Kenya was conducted to evaluate the response of common bean (*Phaseolus vulgaris* L.) cultivar “Rose coco” (GLP 2) to varying rates of N and P application. Simple economic analysis was also carried out to determine monetary returns due to the use of N and P fertilisers. Nitrogen applied at 20, 40, and 80 kg ha<sup>-1</sup> significantly ( $p < 0.05$ ) increased grain yield by 73, 106 and 170%, respectively compared to control. Phosphorus applied at 40 and 80 kg ha<sup>-1</sup> also significantly ( $p < 0.05$ ) increased grain yield by 35 and 3%, respectively. Nitrogen significantly ( $p < 0.05$ ) increased N, P, K and Mg accumulation in the grain. The accumulation increased with increasing rates of N application. However, N did not significantly increase the concentration of macronutrients in the grains. Phosphorus significantly ( $p < 0.05$ ) increased accumulation of N and Mg only in grain, but did not significantly affect phosphorus, calcium and potassium accumulation in grain.

**Key words:** Kenya, nutrient accumulation, *Phaseolus vulgaris*

### **Influence of wheat straw mulch on soil degradation and wheat yield crop in Uasin Gishu District in Kenya**

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Experiments were conducted to evaluate the effects of placement and rate of mulch on yield of wheat crop in Chepkoilel, Uasin Gishu in Kenya. Two positions of placement, namely, partial incorporation and surface application of wheat straw were applied at two rates: 3 and 5 t ha<sup>-1</sup> as follows: (i) 3 t straw mulch incorporated-B1; (ii) 5 tonnes straw mulch incorporated-B2; (iii) 3 tonnes straw mulch surface applied-M1; and (iv) 5 tonnes straw mulch). Application of straws significantly reduced runoff and soil loss. Runoff was highly correlated with soil loss. Regardless of the application rate, surface mulch was more effective and, hence, superior to partial incorporation of straw. Similarly, 5 tonnes straw was more effective than 3 tonnes straw in reducing both runoff and sediment loss. Generally, placement method was more effective than rates of application in controlling runoff and soil loss. Nutrient losses in sediments expressed as "enrichment ratios" (E.R.) revealed significant losses of soil OM%, available phosphorus and total nitrogen. It was, however, difficult to describe the mechanism by which mulch influences E.R. Apparently, less nutrients were lost under the mulch treatments owing to reduced sediment loss. By the end of the season, the levels of OM, pH, available P, and exchangeable K<sup>+</sup> and Na<sup>+</sup> increased. Straw mulch application did not influence soil physical properties.

**Key words:** Enrichment ratio, nutrient losses, phosphorus

### **Effect of soil incorporated legume leaf prunings on soil productivity in alley cropping systems in Kenya**

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Crop yields on small-scale farms in central Kenya highlands continue to decrease due to declining soil fertility, resulting from continuous cropping without adequate replenishment of nutrients. A study was conducted to investigate the feasibility of using leaf prunings of *Calliandra calothyrsus* Meissn and *Leucaena leucocephala* (Lam.) de Wit for soil fertility and productivity improvement. Alley and sole cropping systems were studied in an experiment located at KARI's Regional Research Center's Agroforestry site in Embu District in Kenya. Generally, sole cropped treatments had consistently higher maize grain yields than alley cropped treatments in all seasons. Also, the fertiliser treatments performed better in terms of maize and bean yields than the leaf incorporated and the alley cropping treatments. Infiltration rate and total N increased in treatments with leaf prunings incorporated and with tree hedges. Calcium decreased across the seasons in all treatments, but generally less in the treatment where prunings were added. Addition of prunings did not cause significant changes in soil pH, P, K, Na, Mg, Mn, organic carbon levels, and bulk density among treatments in all seasons. Feasibility of using leaf prunings for soil improvement in an alley cropping system was found to be limited.

**Key words:** *Calliandra calothyrsus*, *Leucaena leucocephala*, maize, phosphorus

## **Comparative changes in soil fertility and crop yields of intensively cropped small-holder farms in Machakos District, Kenya**

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About 80% of Machakos District is arid or semi-arid, and the soils are low in plant nutrients (nitrogen and phosphorus) and organic matter. Intensive cropping of these medium to low potential areas, exerts heavy pressure on the soil resource; resulting in lower crop yields. This study was conducted to monitor soil fertility and crop yields from consecutive cropping of the land, and to investigate the effects of various cropping systems on soil fertility and crop production. An on-station component was conducted on seven-year old runoff plots located at the National Dryland Farming Research Centre, Katumani. The on-farm experiment took place on newly opened farms in the Kathekakai Settlement Co-operative Farm in Machakos district. The cropping system involved two traditional systems, viz.; widely spaced maize (*Zea mays*) monocrop with no mulch or fertiliser, and a maize and a bean (*Phaseolus vulgaris*) intercrop, also with no mulch or fertiliser. Other cropping systems involved increased fertiliser application, mulch rates and plant population. Generally, soils in the newly settled farms at Kathekakai had not deteriorated markedly, although there were signs of possible decline in soil fertility where the farmers continued to cultivate their farms without nutrient restitution. Yield data revealed that high and sustained crop yields in Machakos district can be obtained with judicious and balanced fertiliser application, combined with organic amendments. In spite of economic feasibility of the traditional systems involving widely spaced monocrop maize, and maize and beans intercrop; these systems were found to be non-sustainable. On the other hand, a cropping system involving high maize population, application of up to 70 kg N ha<sup>-1</sup> plus 10 kg P ha<sup>-1</sup>, and extra stover mulch was found to offer a better option for the farming community in this semi-arid district. It was established that soil organic matter fractions could provide means for monitoring soil productivity and hence predicting crop performance.

**Key words:** Inorganic fertilisers, *Phaseolus vulgaris*, *Zea mays*

## **Phosphate rock and vsm inoculation effects on growth of trees in two acid soils in Kenya**

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Establishment of trees from the seedlings is the most critical phase in afforestation. Seedlings are prone to environmental and biotic factors such as water stress, nutrient deficiencies and/or toxicities, pests and disease as a result of their fragile nature. Various workers have shown the importance of applying nitrogenous and phosphorus fertilisers to potted tree seedlings. In Kenya, fertiliser application to nursery potting media has hardly been tried. Three green house studies using acid Acrisol and Andosol from western and eastern Kenya respectively, and six agroforestry tree species, namely *Leucaena leucocephala*, *Gliricidia sepium*, *Sesbania sesban*, *Cassia siamea*, *Grevillea robusta* and *Eucalyptus grandis* investigated phosphorus availability from Minjingu phosphate rock (MPR). In the first experiment, one month old seedlings received 0 (control), 52 (RP<sub>1</sub>) and 77 (RP<sub>2</sub>) kg P ha<sup>-1</sup> in 2 kg soil. In the second experiment, the previous phosphate rock rates, *G. robusta*, *L. leucocephala* and the Acrisol

were used with VA-mycorrhizae inoculum being included. In both experiments *L. leucocephala* was not inoculated with rhizobium bacteria. At 19 weeks after transplanting, 77 kg P ha<sup>-1</sup> improved height of *L. leucocephala* significantly and the phosphate rock rates differed significantly ( $p < 0.05$ ) from the control in root collar diameter for *G. robusta* growing in Acrisols. Application of phosphate rock in Andosols, significantly ( $p < 0.05$ ) reduced height and root collar diameter of *G. robusta* and *C. siamea*. In the second study, significant increases of up to 121% in height and root collar diameter and 4.5 times in biomass over the controls were observed with both species. Nodulation of *L. leucocephala* was variable, but none was observed with the controls. In the third experiment using the <sup>32</sup>P isotope dilution techniques the Acrisols and all six agroforestry tree species were used. Phosphorus was applied at 129 mg P 5 kg<sup>-1</sup> soil as MPR or Triple Superphosphate (TSP) and the pots were divided into three sequential harvests, 3, 6, and 9 MAT (months after transplanting). <sup>32</sup>P isotope labelled fertiliser was applied uniformly at the beginning, at 3 and 6 months. Phosphorus bioavailability test showed that the soil had high fixing P ability with the ratio of <sup>32</sup>P activity remaining and total <sup>32</sup>P in solution (r1/R) being 0.03 and 0.015 before and after incubation, respectively. Increase in *L. leucocephala* height was almost five fold at 6 months to 3 months after transplanting. Minjingu phosphate rock gave significantly higher root dry weight with *S. sesban*, *G. sepium* and *E. grandis*. Percent phosphorus derived from fertiliser and relative availability of rock phosphate as determined by isotope dilution indicated that at 3 months after transplanting, *L. leucocephala*, *G. sepium* and *C. siamea* derived 2.93, 1.06 and 1.04 times more phosphorus, respectively from phosphate rock than TSP, and at 9 months after transplanting derived 3.71 times more phosphorus from Minjingu phosphate rock compared to TSP. Interactions were highly significant ( $p < 0.001$ ) and at 3 months after transplanting there were significant increases of up to 150-200% in growth and phosphorus uptake where phosphorus was applied.

**Key words:** *Cassia siamea*, *Gliricidia sepium*, *Eucalyptus grandis*, VA-mycorrhizae

### **Factors influencing fertiliser use and perception of the rock phosphate packs by smallholders in western Kenya**

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Food insecurity is common in most smallholder households in western Kenya. Maize yields stand at 0.3 t ha<sup>-1</sup> on the average. It is in light of this that the scientists under the Phosphorus Resource Exploratory Project (PREP) at Moi University developed a fertiliser technology package called 'PREP-pack'. PREP pack is an alternative technology that is affordable and is aimed at replenishing lost phosphorus and nitrogen with the use of Tanzanian rock phosphate (Minjingu rock phosphate) and intercropping of maize with legumes. This study firstly, determined the socio-economic factors that influence the quantity of phosphate fertiliser purchased by farmers in Vihiga district in Kenya. Secondly, it assessed the performance and the farmers' perception of rock phosphate PREP-Packs in Vihiga, Busia and Siaya districts. Secondary data were collected from government and literature. Primary data were collected using two separate questionnaires through interviewing of 65 farmers. A regression analysis was used to estimate the fertiliser demand function. The average pack requirements and the sample proportions of respondents requiring various quantities of the PREP pack were estimated, in analyzing the perception of the PREP pack. Years of formal education, land size and fertiliser credit purchase were positively related to, and significantly influenced the quantity

of fertiliser purchased. The price of fertiliser and family size were inversely related to, and significantly influenced the quantity of fertiliser purchased. The use of manure, levels of extension contact, farm income, maize yield and the farmers' age did not significantly influence fertiliser purchases.

**Key words:** Maize, manure, Minjingu rock phosphate, PREP packs

### **Response of maize to split application of urea and green leaf manure in western Kenya**

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Soils in western Kenya have low nitrogen and phosphorus due to inherent low soil fertility, aggravated by continuous cropping with little or no use of fertilisers. A study was carried out to assess split application of *Tithonia diversifolia* green leaf manure as a source of nitrogen for maize, to substitute urea as a nitrogen source. A field experiment was conducted in a Kandialdic Eutrudox soil at Khwisero, Butere district in western Kenya, followed by a residual. Nitrogen at the rate of 60 kg N ha<sup>-1</sup> was split applied at planting and at six weeks after sowing as follows: 60:0, 40:20 and 0:60. Tithonia and urea were used as nitrogen sources on both low P (10 kg P ha<sup>-1</sup>) and high P (100 kg P ha<sup>-1</sup>) soils. Results for the cumulative maize grain yields for two seasons were comparable with either *T. diversifolia* or urea as the N sources for maize in both low and high P soils. High P application of tithonia all at planting time gave significantly higher grain yields (5.4 t ha<sup>-1</sup>) compared with the other N application timings. For urea, split application of 1/3 at planting followed by 2/3 at six weeks gave the highest yields (6.1 t ha<sup>-1</sup>). In contrast with low P soils, tithonia showed significantly lower yields when applied at planting (2.4 t ha<sup>-1</sup>) compared with the other N timings, which were similar. However, for urea, split application of 2/3 at planting followed by 1/3 at six weeks gave the highest yields (3.8 t ha<sup>-1</sup>). The results showed that the mode of application of tithonia as N source for maize differed from urea and varied with the level of phosphorus applied. In low P soils, tithonia gave net negative economic returns of Kenya shillings (Ksh.) -2170 ha<sup>-1</sup> because of high labour costs compared with the net positive returns of Kenya shillings 5740 ha<sup>-1</sup> for urea during the first season. A similar, but slightly improved trend was observed when the two seasons were combined where tithonia gave net negative economic returns of Ksh. -350 ha<sup>-1</sup> compared with urea's Ksh. 6580 ha<sup>-1</sup>. Tithonia application, at six weeks after planting, showed higher net economic returns of Ksh.5600 ha<sup>-1</sup> compared with Ksh.980 ha<sup>-1</sup> for urea in low P soils, hence is recommended for the region.

**Key words:** Economic returns, nitrogen, phosphorus, *Tithonia diversifolia*

### **Soil phosphorus fractions influenced by phosphorus and nitrogen sources in western Kenya**

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The effect of inorganic phosphorus fertilisers on soil P fractions in the highly weathered soils of the sub-humid tropics is poorly understood. A study was conducted to evaluate effect of

triple super phosphate (TSP, 20% P) and Minjingu Phosphate Rock (MPR, 13% P, 3% citrate-soluble P), on soil phosphorus fractions. The two sources of P applied at 0, 50 and 250 kg ha<sup>-1</sup> each were combined with 60 kg N ha<sup>-1</sup> applied as either urea or tithonia [*Tithonia diversifolia* (Hemsley)] A. Gray]. All the fractions were correlated against maize yield from the next harvest. Phosphorus applied at the rate of 250 kg P ha<sup>-1</sup>, as either TSP or MPR had a significant increase on the labile and moderately labile inorganic Pi fractions. Enrichment of Pi above the control indicates that use of inorganic P fertilisers (either TSP or MPR) can substantially increase P in both the liquid capital (approximated by Resin + NaHCO<sub>3</sub> extractable inorganic P) and reserve capital (approximated by NaOH + HCl extractable P) fractions. Extractable inorganic P varied between the P sources and sites. For example, the TSP-treated soil, NaHCO<sub>3</sub>-Pi and NaOH-Pi were the major P sinks in both soils; while for MPR treated soils the Resin and HCl extractable inorganic P fractions were highest in the Alfisol. MPR treatments showed moderate increase between the two seasons in both the labile (RO-Pi and NaHCO<sub>3</sub>-Pi) and moderately labile (NaOH-Pi) fractions at both sites. Extractable Pi fractions from tithonia treatments were generally slightly higher than those from urea treatments. The organic P (Po) fractions were not influenced by the P rate, P source or N source (tithonia vs. urea). Coefficients of determination (R<sup>2</sup>) of P pools against maize yield were generally higher for TSP as compared with MPR on both sites. Non-sequential RP-Pi, NaHCO<sub>3</sub> + EDTA-Pi had stronger correlations with maize yield than Pi fractions from the sequential extractions in TSP-treated soils. Resin-Pi (both sequential and non-sequential) had the strongest correlations with maize yields in MPR-treated soils. The organic P and microbial biomass fractions (P and C) were not significantly correlated with maize yields. The relative agronomic effectiveness (RAE), determined as increase of maize yield due to MPR divided by increase due to TSP, expressed as a percentage, varied with both site and season. The RAE for MPR with tithonia as N source, averaged over both seasons, was 77% on the clay loam and (94% on the sandy clay loam, while with urea, RAE averaged 87% on the clay loam and 113% on the sandy clay loam.

**Key words:** Labile phosphorus, Minjingu phosphate rock, resin-P

### **Effect of rock phosphate, urea and rhizobium inoculation on yield and nutrient uptake of maize-soybean intercrop on the acid soils of western Kenya**

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Soil fertility depletion in western Kenya is a major cause of low agricultural productivity and its amelioration, through nutrient replenishment strategies is viewed as necessary component in the achievement of food security. The magnitude of soil fertility decline is huge, with widely distributed symptoms occurring through the expression of unproductive, nutrient-deficient “patches” within farmers’ fields. Nitrogen and phosphorus are the most important plant nutrients but they are the most limiting in the tropical African soils. Phosphate Evaluation Project-Package (PREP-PAC) is an inexpensive “kit” designed to treat the “low fertility patches”. PREP-PAC consists of two 2 kg Minjingu Rock Phosphate (MPR), 0.2 kg urea, legume seed, Biofix®, (rhizobial inoculant) and detailed use instructions, and is assembled at a cost of Kenya shillings (Kshs.) 41.2 per unit. A study was conducted in five farms selected from Uasin Gishu, Siaya, Bungoma and Kakamega districts in Kenya. These farms were selected based on low soil pH and low available soil P. It was observed from soil analysis that the farms where

PREP-PAC was tested differed in characteristics. But in general, soil pH in all the farms was below 6.0. Available P for all the soils was very low, ranging from 1.2 ppm P in Siaya to 5.2 ppm in Kakamega. Minjingu Rock Phosphate, Biofix® and urea resulted in improved crop yield. Significant interactions were observed between different combinations of the main components. Maize yields ranged from 431 to 6,525 kg ha<sup>-1</sup> across all the sites and seasons. The average contributions for PREP-PAC components for urea, Biofix® and MPR, respectively were; +428, +680, +1511 kg ha<sup>-1</sup> in Siaya, +139, +40, and +78 kg ha<sup>-1</sup> in Chepkoilel, -6, +141, and +804 kg ha<sup>-1</sup> in Kakamega and +74, -205, and +1362 kg ha<sup>-1</sup> in Bungoma. In spite of significant site and treatment differences observed for soybean yield, these yields were very low (250 and 504 kg ha<sup>-1</sup> in 1998 and 45 and 320 kg ha<sup>-1</sup> in 1999. There was significant residual effect of PR ( $p < 0.05$ ) on maize and soybean yield in the second season crop in Siaya. Nutrient uptake varied greatly between maize and soybean, across the sites and seasons. The use of PREP-PAC resulted in higher uptake of N, P and K. With the exception of the first season at Siaya, for which nutrient uptakes were partitioned, the total nutrient uptakes were as follows: total N for grain and stover/trash uptake across the sites and seasons ranged from 15 to 171 kg N ha<sup>-1</sup> for maize and 4 to 48 kg N ha<sup>-1</sup> for soybean. Phosphorus uptake was between 1 and 10 kg P ha<sup>-1</sup> for maize, and 0.1 to 2.6 kg P ha<sup>-1</sup> for soybean. For the partitioned grain and stover/trash N and P uptakes were as follows: 109.6 and 61.6 kg N ha<sup>-1</sup> in grain, 6.92 and 2.84 kg P ha<sup>-1</sup> in stover/trash for maize and soybean, respectively. Significant site differences were also observed with respect to total returns ( $p < 0.05$ ), return ratio ( $p < 0.01$ ), value of maize ( $p < 0.01$ ) and value of soybean ( $p < 0.05$ ).

**Key words:** Minjingu rock phosphate, nitrogen, phosphorus, PREP PACK

### **Growth, nutrient accumulation and genetic variability of *Tithonia* provenances and agroforestry species under phosphorus fertilisation in western Kenya**

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*Tithonia diversifolia* or Mexican sunflower is widely distributed throughout the tropics, and shows promise as an agroforestry species for improved fallows or biomass transfer. This study compared *Tithonia* with several leguminous agroforestry species, and also investigated growth and genetic variability in some east African provenances of *Tithonia*. The study determined the growth and tissue N, P and K concentration and accumulation by *Tithonia diversifolia*, *Crotalaria grahamiana*, *Tephrosia vogelii* and *Sesbania sesban* after 12 weeks of plant growth. Another study determined the effect of *T. diversifolia* provenances on growth and tissue N, P and K concentration and accumulation at P limiting and non-P limiting conditions on several soils of western Kenya. In experiment 1, four plant species were grown in pots of 4 different P-deficient soils, with or without fertiliser P and with no other nutrient additions. Of the 4 species, *Tithonia* produced the least aboveground and total biomass, and accumulated less total N, P and K than the other species. Nitrogen, P and K concentrations varied within species, soil type and P fertilisation, with P fertilisation causing an increase in P concentration, no effect on N concentration and a decrease in K concentration. Root to shoot ratio was higher in *Tithonia* than for the other species, varying somewhat with P additions. All plants were endomycorrhizal, with all species having >50% of fine root length infected. *Tephrosia* showed a higher infection rate than the other 3 species by over 20%. Infection rate was significantly lower ( $p < 0.001$ ) in P-fertilised soils by about 10%. There were no soil differences

in infection rates. Six provenances of *Tithonia* (2 Kenyan, 3 Ugandan and 1 from Philippines) were grown in pots all nutrients except P applied in sufficiency, and with or without P addition. Height was different among provenances ( $p < 0.05$ ), with the Ugandan provenance as a group growing slightly better by about 10 cm than Kenyan or Philippines provenances. Phosphorus addition eliminated the slight differences in growth. There were no significant differences in total biomass production or N, P and K concentration and accumulations among provenances. Polymerase chain reaction (PCR) based Randomly Amplified Polymorphic DNA (RAPD) analysis showed differences among provenances, with Kenyan and Ugandan provenances not separate into two distinct groupings. There was substantial within-provenance diversity. Endomycorrhizal infection ranged from 34-54% for the different provenances, with significant differences by country ( $p < 0.05$ ). The Ugandan provenances as a group tended to have a lower infection rate. *T. diversifolia* could better be used in biomass transfer technology while the legumes could be better used in improved fallow technology.

**Key words:** *Crotaria*, *Sesbania*, *Tephrosia*, *Tithonia diversifolia*

### **Effect of combining organic residues with phosphate rock and triple superphosphate on phosphorus sorption and maize performance in western Kenya**

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Organic materials upon decomposition reduce phosphorus sorption by soils and increase its availability. However, most studies in these areas have been carried out under green-house conditions, which give unrealistic recommendations. The aim of this study was to assess the P sorption characteristics of one major soil type (Ferralsol) and reduce P sorption by combining agricultural based organic materials of different qualities with inorganic fertiliser. The study was carried out both on station at Uasin Gishu District, Chepkoilel Campus, Moi University for both field and incubation studies; and off station (Busia and Siaya Districts field experiment). In Busia, three rates of Minjingu phosphate rock (MPR) (0, 30 and 60 kg P ha<sup>-1</sup>) were combined with chicken manure (CM), farm yard manure (FYM) and sugar baggasse (SB) at 0 and 2 t ha<sup>-1</sup> each. In Uasin Gishu, two sources of P, namely, MPR and triple superphosphate (TSP) at 0, 20 and 40 kg P ha<sup>-1</sup> each was combined with CM and FYM at 0 and 2 t ha<sup>-1</sup> each. In Siaya, two rates (0 and 60 kg P ha<sup>-1</sup>) of MPR was combined with maize stover (MS) and FYM at 0, 1 and 2 t ha<sup>-1</sup> each. The same treatment was used in Busia district, with an extra treatment of 60 kg P ha<sup>-1</sup> from the study. The sorption data were analysed to be fitted to the Langmuir equation. Sorption capacity of the soil increased with increase in the rate of MPR, whereas TSP reduced the P sorption throughout the incubation period. Chicken manure proved superior in reducing the P sorption, while sugar baggasse was inferior. Poor correlation coefficients between sorption parameters with soil pH, aluminium oxide or iron oxide in Busia and Uasin Gishu soils as compared to Siaya soils suggested that they were not dominant factors on sorption capacities of these soils. Combining organic materials with MPR or TSP significantly ( $p < 0.005$ ) increased extractable P. Significant ( $p < 0.005$ ) treatment effect on maize grain yield increases occurred in Busia and Siaya sites in all the seasons. High maize grain yield of up to 7.5 t ha<sup>-1</sup> was recorded in Busia in the second season (2001 Long rains), MPR had a residual effect in Busia probably because of the high P deficiency and P release pattern in soils of this area. Combining MPR at 30 kg P ha<sup>-1</sup> with high quality organic materials, e.g., CM may help to reduce P sorption in

highly P depleted sites and increase its availability. In Busia, MPR at 30 kg P ha<sup>-1</sup> combined with FYM (2 t ha<sup>-1</sup>) was considered the best rate in increasing P uptake, P recovery and N use efficiency. Across the three sites, the highest incremental net benefit of Kenya shillings 51,477 was obtained when TSP was applied at 20 kg P ha<sup>-1</sup> over the two maize cropping seasons in Uasin Gishu. This was closely followed by cm (2 t ha<sup>-1</sup>) combined with MPR at 60 kg P ha<sup>-1</sup> (Ksh. 51,244) in Busia site over the three maize cropping seasons.

**Key words:** Baggase, cattle manure, ISP, pH

### **Economic evaluation of groundnut production technologies in western Kenya**

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A study was conducted on-farm to test crop specific technological innovations in groundnut growing western Kenya; Siaya, Busia and Teso. The objective was to generate technologies for small-scale groundnut farmers on the basos of varying time of planting, weeding, and fertilisation of groundnut fields using organic and inorganic fertilisers. Data on groundnut technology used, yields, resource availability and use of farmers' characteristics were collected through administration of detailed questionnaire to a sample of 332 farmers from the three study districts. Benefits and costs of each technology were computed through the use of partial budgets. Non-frontier efficiency model was used to evaluate the relative technical efficiency of the different categories of technology adopters. Cobb-Douglass production function was fitted to the cross-sectional data generated from the survey. The average cost of non-adopters in producing groundnuts was lower than for adopters of organic or inorganic fertilisers. This resulted from inefficient resource allocation. All categories of farmers experienced increasing returns to scale, meaning that use of additional inputs in groundnut production would result in higher yields. Use of inorganic fertilisers gave high benefit-cost ratios. Organic manure had the lowest benefit-cost (2.2:1) even compared to that obtained from the control (2.4:1). This was attributed to the high cost of labour required to use this technology. Use of *Rhizobium inoculant* gave a benefit cost ratio of 2.5:1.

**Key words:** Inefficient resource allocation, production efficiency

### **Economic analysis of the use of non-conventional fertiliser technologies in Vihiga District, Kenya**

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This study performed an economic analysis of the commonly used non-conventional fertilizer technologies (FYM, compost, Agroforestry shrubs and *Tithonia diversifolia*) used on food production in Vihiga district in Kenya. Most farmers in Vihiga are low income earners. The problem of low soil infertility and inability of farmers to use purchased inputs has resulted in efforts for promoting non-conventional fertilisers. Past studies have emphasised yield responses to the new technologies at the expense of economic aspects, yet adoption of the

technologies is subject to farmers' perception of benefits and limitations to their use. A total of 150 farmers from three out of six divisions of Vihiga were interviewed. Primary data were mainly used for analysis. Descriptive statistics and econometric (simple, linear and binomial Logit regression) models were used to analyse data. Use of technologies on maize and bean production led to significant profitability differences between the technologies at ( $p < 0.05$ ). Levels of FYM was significantly below those recommended by Kenya Agricultural Research Institute. Factors affecting adoption of organic matter technologies on the other hand varied widely between technologies.

**Key words:** FYM, soil fertility, *Tithonia diversifolia*

### **Market testing of PREP-PACK: A new technology in soil fertility management for resource poor smallholder farmers in western Kenya**

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The Phosphate Rock Evaluation Project (PREP) has contributed a partial dilemma of meaningful smallholder involvement in nutrient replenishment through development of an inexpensive "kit" designed to restore productivity of the soil, the PREP-PAC. The kit consists of Minjingu Rock Phosphate, urea, legume seed, rhizobial inoculant and detailed instructions. It is now being field tested on 250 farms. Preliminary results and farmers' responses are extremely promising. However, the full benefits from applying PREP-PACs can only become realised from its hand-over to the private and competitive market, a process that is inadequately considered. This study assesses the retailers' demand and strategy in marketing the new product, challenges in its marketing and strategies to improve the products market. Observation and survey were used to establish the PREP-PACs' market potential and effective demand. A sale of 57% of total supply of 245 PREP-PACs ordered as initial demand by 44 retailers was achieved within a month. PREP-PAC was sold at an average price of Kenya shillings (Ksh.) 36.10. Only reputation of fertiliser supplier affected the marketability of the product significantly ( $p < 0.0004$ ) of all PREP-PAC attributes. This was due to adulteration of fertilisers and customer product loyalty. Retailers' characteristics, which significantly influenced PREP-PACs' marketability were ownership of retail outlet ( $p < 0.001$ ), selling fertiliser repackaged into smaller quantities ( $p < 0.0008$ ) and fertiliser leads in small sales return ( $p < 0.0002$ ). Other factors considered that were not significant included sex of stockist, amount of diammonium phosphate (DAP) they sold, experience in fertiliser marketing and the number of fertiliser types. The level of PREP-PAC sale was significantly affected by: retailers' perceptions of PREP-PAC marketability ( $p < 0.005$ ), retail outlet ownership ( $p < 0.007$ ), amount of DAP sold ( $p < 0.001$ ), sex of stockist ( $p < 0.017$ ), selling of fertiliser repackaged into small quantities ( $p < 0.074$ ), and ratio of customer informed of its availability ( $p < 0.060$ ), and its retailing price ( $p < 0.049$ ). Factors found to be insignificant in influencing PREP-PAC sales were experienced in fertiliser marketing ( $p < 0.102$ ), displaying position in the store ( $p < 0.133$ ), ratio of area under fertiliser ( $p < 0.438$ ) and the number of fertiliser types sold ( $p < 0.772$ ). Market potential for the PREP-PAC exists and what is required is the stimulation of effective demand through promoting the product to farmers and using retailers to market the product. PREP-PAC could be promoted through product extension agents, agricultural extension agents, exhibition in the agricultural shows and farmers' field days and advertisement of the product using the media. Product improvement, price reduction

and persistence supply of the product to retailers although the demand may be low will definitely lead to high effective demand.

**Key words:** DAP, market potential, Minjingu rock phosphate

### **Effect of Minjingu phosphate rock on maize yield and changes in soil phosphorus under improved fallows in western Kenya**

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Soil fertility decline mainly due to nitrogen and phosphorus depletion has led to low and declining crop yields on small-scale farms in western Kenya. Although attempts to restore soil fertility through use of soluble fertilisers have been tried, financial constraints limit farmers from the adoption of this technology. This study aimed at to evaluating the use of a low cost technology that utilises Minjingu Phosphate Rock (MPR), which could effectively supply P to the maize-short fallow intercrops, and the provision of N to the successive maize crops through the incorporation and decomposition of the fallow biomass. On-farm field experiments were carried out in Busia, Siaya, and Bungoma Districts of western Kenya. Minjingu phosphate rock (an effective P source especially in the acid soils) was applied at four rates (0, 20, 40 and 60 kg P ha<sup>-1</sup> MPR) and two short fallow species (*Crotalaria grahamiana* and *Tephrosia vogelii*) were planted in between the maize rows. After the harvest of maize and fallow biomass in the first season, the fallow biomass was chopped and incorporated into the soil at planting for the provision of N mainly in the subsequent seasons. In the second season, maize was planted in Busia and Siaya, while beans were sown in Bungoma due to rainfall variations. Soil sampling to assess the changes in soil properties from the MPR and short fallow incorporation was carried out before planting. Changes in nitrate N were also monitored in the first season (16 WAP) and after fallow incorporation in the second season (32 WAP). The Net Present Values (NPV) i.e. return to land, net benefits and the marginal rate of return (MRR) were calculated to establish the economic rate of MPR in the different sites. In the first season, there were significant increases in available soil P at harvest of the first maize crop in Busia and Bungoma due to addition of MPR. MPR at 60 kg P ha<sup>-1</sup> gave the highest available P release in the sites. In the second season, 40 kg P ha<sup>-1</sup> MPR and 0.8 t ha<sup>-1</sup> *Crotalaria* biomass ha<sup>-1</sup> led to higher P release from the residual MPR than the same rate of *Tephrosia* biomass and MPR combination in the two sites. Soil nitrate N increased with time. The highest levels of nitrate N were found after the incorporation of the short fallow biomass, whereby, *Tephrosia* biomass contributed to the highest release of mineral N in Busia and Siaya. Significant maize yields were noted in Busia (p<0.008), Siaya (p<0.001) and Bungoma (p<0.046) in the first season. Application of MPR at 60 kg P ha<sup>-1</sup> gave the highest yields increases, (183 and 138%) above the control treatment in Busia and Bungoma, respectively. In the second season, combination of 60 kg P ha<sup>-1</sup> MPR and 1.7 t ha<sup>-1</sup> *Crotalaria* biomass ha<sup>-1</sup> gave the highest yields in Busia. Low financial returns from treatments were realised from Busia due to high production costs. Improved fallows (*Crotalaria*) were found to have beneficial effects on the maize yield and to improve the soil P status.

**Key words:** *Crotalaria*, marginal rate of return, nitrogen, *Tephrosia*

### **Agronomic evaluation of Tanzanian and Ugandan phosphate rocks for maize production in western Kenya**

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Soil phosphorus deficiency in western Kenya is a major cause of low maize yields, yet commercial phosphorus fertilisers are unaffordable for most smallholder farmers. Local phosphate rocks (PRs) are an alternative P source, but most are uncreative. Surveys of natural phosphate resources in East Africa reveals availability of large amounts of phosphate from Uganda (Bukusu and Butiriku carbonate complexes). Small scale, appropriate technologies were developed for grinding and sieving the collected phosphate, concentrating the phosphate by removal of impurities through magnetic separation, and blending the concentrate with soluble P fertilisers. A number of concentrates and blends were prepared for agronomic evaluation. Several East African PRs in one field and two pot studies using maize (*Zea mays*) as a test crop, were carried out as follows: Four Ugandan phosphate rocks (Busumbu hard and Busumbu soft, Bududa and Bukiribo) with citrate solubility 0.3 to 1.1%, Busumbu PRs (soft and hard) blended with triple superphosphate (TSP) or monoammonium phosphate (MAP) at various ratios and Minjingu phosphate rock from Arusha Tanzania with citrate solubility of 3.4%. The materials were tested to for effectiveness as a P source for maize. The soils were collected from Nyabeda, Kondik, Khwisero and Malava, which were acid and P deficient. Maize responded positively to increasing levels of P applied as TSP in the field study, while maize response to applied TSP in the pot experiment showed two response phases (0-50 mg P kg<sup>-1</sup> soil and 50-300 mg P kg<sup>-1</sup>). Maize growth with Ugandan BPR soft alone was not different ( $p>0.05$ ) from the control both in the field and pot studies. The Ugandan BPR hard alone was significantly different ( $p<0.05$ ) from the control. The other Ugandan Bukiribo PR was significantly different ( $p<0.05$ ) from the control in the pot studies. The Relative Agronomic Effectiveness (RAE) of hard BPR relative to TSP was 55 and 61%, while that of MPR was 75 and 91% for the long rains (LR) and short rains (SR), respectively. The RAE for Ugandan PRs ranged from 10 to 32%, while for MPR averaged 92%.

**Key words:** Magnetic separations, TSP, *Zea mays*

### **Use of manure and crop residues to improve the solubility of Minjingu phosphate rock for phosphorus replenishment in depleted acid soils of western Kenya**

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Phosphorus is one of the limiting nutrients to crop productivity in western Kenya. One of the common correction practices is the use of inorganic fertilizers, however, their use is limited by high costs, especially for most small scale farmers. There is evidence indicating positive response of crops to direct phosphate rock (PR) application as well as its residual effects. The objective of this study was to improve the solubility of PR through combinations with crop residues, manure and compost. An experiment was set up at Chepkoiel Campus, Moi University to study the appropriate rate of PR application, 0, 25, 50 and 75 kg P ha<sup>-1</sup> for optimum crop yield when combined with 2 t ha<sup>-1</sup> of readily available organic material and sulphur. An on-farm

experiment was also set up in the first cropping season at Busia, Siaya and Kakamega districts representing two soil types, Feralsol and Acrisol. Treatments in the field included PR applied at 0 and 60 kg P ha<sup>-1</sup>, and maize stover and FYM at 1 and 2 t ha<sup>-1</sup> each. Soil samples were taken when the maize crop was at 1 meter height, tasselling, harvesting and planting residual crop and harvesting, and analysed for soil extractable P and pH. Plant samples were also taken at 1 meter height, tasselling, harvesting and only at harvest for the second crop. Application of PR combined with organic materials increased soil extractable P; implying improved solubility of PR with higher level of PR and between the sampling periods (4 and 9 weeks). Application of PR at different rates combined with organic materials also increased pH slightly, but with sulphur combinations lowered pH significantly. The same trend as that of extractable P was observed for P content and uptake, with highest P content obtained from sulphur combination with PR and highest P uptake from chicken manure combinations. Highest response was obtained at 50 kg ha<sup>-1</sup> PR combined with Chicken manure or compost while for maize stover, sulphur and FYM it was 60 kg ha<sup>-1</sup> applied as PR. In the field, application of all treatments increased soil pH over the growing seasons for all the sites. However, a decline in pH was observed at the end of the second season. Highest Olsen extractable P was observed at harvesting the second crop, at planting second crop and at tasselling in Siaya, Busia and Kakamega, respectively. Combination of PR with FYM or maize stover increased extractable P over the sampling periods. Combinations of PR with either maize stover or FYM increased extractable P compared to when PR, maize stover and FYM were applied alone. Although application of organic materials and their combinations with PR increased extractable P, the level of extractable P remained below 10 mg P kg of soil, which is the threshold for fertiliser application. Yields of maize grain ranged from 1021 to 2,527 kg ha<sup>-1</sup> in Busia, 2,950 to 4,770 kg ha<sup>-1</sup> in Siaya and 4153 to 5835 kg ha<sup>-1</sup> in Kakamega. In general, application of PR combined with 2 t ha<sup>-1</sup> of FYM or maize stover gave a better response than when PR was combined with FYM or maize stover at 1 t ha<sup>-1</sup>.

**Key words:** Olsen extractable, maize, pH, poultry manure

### **Effects of *Euclea divinorum* and *Vangueria madagascarensis* green mulch on soil fertility improvement in west Pokot District, Kenya**

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A field experiment was conducted on two sites in the Semi-Arid parts of West Pokot District, to compare the effects of *Euclea divinorum*, *Vangueria madagascarensis* green leaf manure (GLM) and farm yard manure (FYM) on soil fertility improvement for maize production. Treatments included: *Vangueria*+ *Euclea*, FYM + *Vangueria*, FYM + *Euclea*, FYM + *Vangueria* + *Euclea*. A control with no inputs was included. Lignin percentage was higher for *Euclea* (15%) than *Vangueria* GLM (4%). The concentrations of N, P and K were higher for *Vangueria* (3.9% N, 0.3% P and 1.5% K) than *Euclea* (2.6% N, 0.1%, and 0.8% K). FYM had lower concentrations of N (0.6%) and higher concentrations of P (0.4%) and K (2.3%) compared to GLM used. Observations on decomposing GLM indicated that *Euclea* GLM had not decomposed completely after four months but there were no traces of *Vangueria*. Hence, *Vangueria* GLM is of higher quality compared to *Euclea* GLM. A combination of manures (FYM + *Vangueria* + *Euclea* GLM) resulted in the highest maize grain yields; hence, mixtures

of organic manure better than sole inputs. However, *Euclea* and *Vangueria* GLM have potentials of improving soil fertility and crop production as sole inputs.

**Key words:** Farm yard manure, lignin, nitrogen, phosphorus

### **Economic analysis of maize and beans production using a soil fertility replenishment product in the acid soils of western Kenya**

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Farmers in western Kenya produce crops under diverse biophysical and socio-economic environments. Maize intercropped with beans are the main crops produced for household food consumption with occasional surpluses sold for cash. Recent studies indicate that maize and bean fields are mined of plant nutrients leading to decline in crop yields. The Soil Science Department at Moi University in Kenya, in collaboration with local NGOs has developed a prototype soil fertility replenishment product, PREP-PAC. This product contains 2 kg Minjingu Rock Phosphate, 0.2 kg urea, 0.1 kg of seed legume and corresponding rhizobium inoculant for specific legumes. One PREP-PAC is recommended for application on a 25 m<sup>2</sup> of fertility depleted fields. The objective of this study was to conduct an economic analysis of PREP-PAC use among smallholder farming communities in western Kenya. The study revealed that use of PREP-PAC in soils with low pH, <5.2 increased financial returns on land from Kenya shillings (Ksh.) 8,720 to 8,920 ha<sup>-1</sup>, with a return ratio to PREP-PAC of 1.27. In soils with moderate pH (>5.3), PREP-PAC application increased financial returns on land from Kenya shillings (Kshs.) 12,240 to 27,240 ha<sup>-1</sup>, with a return ratio to PREP-PAC of 1.61. Application of farmers own fertility management practices only increased maize yield (p<0.05) but not bean yield. PREP-PAC application increased both maize and bean yields by 122.3 and 174.2% respectively. Marginal rate of return to PREP-PAC was lower than that of farmers own fertility management practices due to relatively high cost of PREP-PAC compared to farmers own fertility management practices.

**Key words:** Marginal rate of return, Minjingu rock phosphate, PREP-PAC

### **Effect of coppicing improved fallows species on soil nitrogen and Striga in western Kenya**

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*Striga* (*Striga hermonthica*) weed in the inherently infertile soils of Lake Victoria Basin has become a real threat and the largest biological barrier to the production of staple food crops in western Kenya. The use of short duration improved fallows with non-coppicing leguminous trees and shrubs have been found to improve soil fertility, control *striga* weed and increase crop yields. The objective of this study was to assess the efficacy of coppicing improved fallow species in controlling *striga* compared to non-coppicing ones that require re-establishment in every planting season. A study was conducted in western Kenya to assess *striga* emergence following field trials with three coppicing tree species, *Gliricidia sepium*

(gliricidia), *Leucaena trichandra* (leucaena), and *Calliandra calothyrsus* (calliandra) and three non-coppicing tree/shrub species, *Sesbania sesban* (sesbania), *Mucuna pruriens* (mucuna) and *Tephrosia vogelii* (tephrosia). Other treatments included: natural fallow (NF), continuous coppicing without fertiliser (CC-F) and continuous cropping with fertiliser (CC+F). All plots were split into two, with one half receiving nitrogen (N) at 60 kg N ha<sup>-1</sup> and the other 0 kg N ha<sup>-1</sup>. Soil inorganic N content was significantly higher ( $p < 0.001$ ) in the cropping fallows (48.8 kg N ha<sup>-1</sup> for +N and 43.2 kg N ha<sup>-1</sup> for -N sub-plots) than in the coppicing fallows (37.3 kg N ha<sup>-1</sup> for +N and 33.7 kg N ha<sup>-1</sup> for -N sub-plots). Initial *striga* seed count in the soil following maize crop ranged from 42 to 188 seeds kg<sup>-1</sup> of soil. Treatments that had the highest inorganic N content caused the greatest decline of *striga* density. Maize grain yield was in the decreasing order: 6.5 t ha<sup>-1</sup> for the +N and 5.1 t ha<sup>-1</sup> for the -N coppicing fallows, 5.9 t ha<sup>-1</sup> for the +N and 4.9 t ha<sup>-1</sup> for the -N non-coppicing fallows. The yield was least in the control treatments (3.0 for +N and 2.2 for -N sub-plots).

**Key words:** *Calliandra*, *Gliricidia*, *Leucaena*, *Sesbania*, *Striga hermonthica*

### **Influence of conventional and 'Mbili' intercropping systems on yield, nutrient uptake and rooting characteristics of intercrops in western Kenya**

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Food insecurity in sub-Saharan Africa has increased exponentially over the past 35 years and there is seemingly no nearby end to this crisis. Smallholder farms in their endeavor to increase food production, practice cereal-legume-intercropping system. This study was undertaken to enhance the understanding of the 'MBILI' intercropping system (Managing Beneficial Interaction within Legume Intercrops) over conventional intercropping system. 'MBILI' is an intercropping arrangement whereby the maize rows are spread at 50 cm apart in pairs 100 cm apart. Two row of a suitable legume within the gap at 33-cm row; this is as opposed to the conventional recommendation for maize-bean intercropping in western Kenya where maize is planted at a spacing of 75 cm between rows and 30 cm within rows. Beans are planted between the 75 cm rows with 15 cm hill spacing. On-farm experiments were carried out in Bungoma and Siaya Districts of western Kenya. Two intercrops, groundnut/bean with maize were planted within two intercropping systems ('MBILI'/conventional) at two nutrient levels 0 and 150 kg DAP ha<sup>-1</sup> (27 kg N ha<sup>-1</sup>; 30 kg P ha<sup>-1</sup>). Above ground plant materials were sampled at harvest from different treatments to evaluate nutrient uptake and utilisation (N and P) of intercrops. The isotope-dilution method was used to determine the nitrogen derived from the atmosphere. There were significant differences of legumes yields depending on cereal proximity and nutrient level across all sites ( $p < 0.001$ ). Bungoma (long rains) had the highest groundnut yields, ranging from 430 to 893 kg ha<sup>-1</sup> for the 'MBILI' control, and 'MBILI' fertilised plots, respectively. Groundnuts with conventional control and conventional fertiliser plots ranged from 255 to 659 kg ha<sup>-1</sup> respectively. Maize yield was relatively higher in Siaya (long rains) than in other sites and seasons with 'MBILI' at 150 kg DAP ha<sup>-1</sup> (27 kg N ha<sup>-1</sup>; 30 kg P ha<sup>-1</sup>) (within maize/groundnut intercrop) giving the highest yields 4,218 kg ha<sup>-1</sup>. The N and P uptake in the legume and maize grains in all the sites were significantly ( $p < 0.05$ ) affected by nutrient level and row arrangement. Root density was higher and roots grew deeper in the 'MBILI' system than in the conventional system thus, roots in MBILI system were able to access N at deeper layers and, therefore, reduce dependency on N<sub>2</sub> fixed leading to greater overall resource capture. Significant

differences of root densities between the plough layer and subsequent depths was noted within the two intercropping systems ( $p < 0.001$ ).

**Key words:** Bean, groundnut, maize, root density

### **Influence of improved systems and phosphorus fertilisation on arbuscular mycorrhizal fungal symbiosis in maize**

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Formation and functioning of Arbuscular Mycorrhizal Fungi (AMF) symbiosis is important in low input technology, which are considered appropriate technologies to replenish nutrients in soils in the tropics. Although improved fallows are promoted widely in western Kenya as a low input technology for soil fertility, there is little information on extent of AMF colonisation of subsequent crops, and how that is influenced by phosphorus fertilisation. This study was carried out to investigate the effect of improved fallows systems and P fertilisation on AMF colonisation in field-grown maize, and to establish relationship between AMF colonisation and mineral nutrition in maize as well as maize yield. The efficiency of AMF communities in fallow systems was also tested on growth, dry matter production and nutrient concentration in maize. This study was a follow up of a field trial established in 1997 in western Kenya. The trial comprised of four farming systems- Continuous maize (CM), Natural fallow (NF), *Crotalaria grahamiana* fallow (CG) and *Tithonia diversifolia* fallow (TD), with phosphorus (P) ( $50 \text{ kg P ha}^{-1}$ ) and without P fertilisers. Maize crops and fallow species (CG and TD) were grown rotationally for three years, after which, maize was planted continuously to test the residue effect of the fallows. In this study, maize was established during short rains (SR) 2002 and long rains (LR) seasons 2003 in the plots with CG, TD and CM systems, with and without P fertilisation from TSP. Maize roots were sampled at two weeks interval for AMF colonisation. The size of AMF spore communities was determined and different genes of AMF were identified based on spore morphology. AMF communities from TD and CG fallow increased ( $p < 0.05$ ) biomass production, P, K and Zn concentrations of two-month old maize plant with more P concentration ( $p < 0.05$ ) in maize inoculated by AMF communities from TD fallow than those from CM and CG fallow systems. Fallow systems recorded high ( $p < 0.05$ ) nutrient uptake and maize grain yield compared to maize grown in the CM system with more P and N uptake and maize grain yield increases ( $p < 0.05$ ) recorded in maize in the TD fallow than maize in the CG fallow. Although fallow system did not increase the AMF colonisation and function significantly, maize cultivated after TD fallow tended to have higher AMF colonisation during early period of maize growth. Early AMF colonisation related positively ( $r = 0.3$  to  $0.5$ ) with nutrient uptake and maize yield, and was an important variable explaining nutrient uptake in maize. Similarly, P applications increased ( $p < 0.05$ ) maize production and nutrient uptake in all fallow systems and promoted early AMF colonisation significantly ( $p < 0.05$ ) in maize, in the TD fallow.

**Key words:** Colonisation, *Crotalaria*, natural fallow, *Tithonia*

### **Site productivity indexing using maize growth functions in Siaya district, western Kenya**

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Crop yields in many parts of western Kenya are low due to declining soil fertility mainly as a result of continuous cropping that mines nutrients from soils and non-application of fertilizers by farmers. A field experiment was conducted in Sauri Sub-location in Kenya, (i) evaluate the use of bioassays in predicting potential soil productivity using maize root-shoot dry matter allocation ratio, and (ii) derive soil productivity indices based on maize biovolume (stalk-volume) growth curves. Nonlinear mixed effects modeling approach was used to model maize stalk volume/dominant height growth in conjunction with fertiliser treatment. Comparisons of treatment effects over time were integrated with model-building process. A combination of N+P fertiliser application had the highest total growth response. There was no maize growth response to K fertiliser application. There was antagonistic interactions among K, P and N. More research work on interactions of K and/or N and P nutrients is needed to understand how they influence maize growth. There was a high negative correlation ( $r = 0.75$ ,  $p < 0.007$ ) between root-shoot dry matter ratio and the estimated rate of growth parameter. The maize growth pattern across the fields correlated well with spectrally obtained soil quality scores of the fields. Maize growth site indices were developed which may help delineate Sauri farms into crop fields for site-specific management zone, so that a farmer can treat different fields in his farm as management units, thus apply the little inputs he can afford in a rotational way instead of spreading the little over the whole farm.

**Key words:** Nitrogen, phosphorus, potassium, productivity index

### **Monitoring nutrient flow and use of organic and mineral nutrients sources of for enhanced maize production in central Kenya**

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There is a great concern over soil fertility decline in arable east African highlands. Therefore, understanding soil fertility in agro-ecosystems is of importance in improving crop production at spatial or regional levels. This study evaluated soil fertility levels in selected farm typologies; different soil fertility replenishment practices in central Kenya and their sustainability using Nutrient Monitoring (NUTMON) and how to improve maize production using integration of organic with mineral sources of nutrients. This study was carried out in three districts of Kirinyaga, Maragua and Kiambu in central Kenya, where a Participatory Learning and Action Research (PLAR) prior to all the other studies. The PLAR participants (farmers, Ministry of Agriculture extension officers and scientists from KARI) classified the farm typologies according to: Good soil fertility managers (Class 1), medium soil fertility managers (Class 2) and poor soil fertility managers (Class 3). Further, the farmers classified their farms into three different soil fertility patches according to crop performance. High yielding portions were classified "Good", moderate yielding "Medium" and low yielding "Poor". Soils were sampled from the three different farm typologies and soil fertility patches in each farm earlier classified. The results showed that class 1 farms had more soil total N than Class 3 and all the farms differed significantly

( $p < 0.05$ ) in the levels of soil nutrient contents across the farm typologies. Soil fertility patches within the same soil fertility management class showed no significant difference ( $p < 0.05$ ) in Kirinyaga and Maragua districts, though there were variations in extractable soil phosphorus and exchangeable potassium, particularly in Maragua class 1 farms (52-73%). In Kiambu, significant differences were observed in soil nutrient levels across the farm typologies and also in soil fertility patches within the same soil fertility management classes. Significant differences were observed in fertility levels in farm fertility patches within the same soil fertility class in all the districts. NUTMON studies were carried out within the same soil fertility management classes. Farmers in Kirinyaga and Maragua allocated large portions of their farms to food crops (maize or maize/beans), while in Kiambu, the largest portions of the farms were allocated to horticultural crops and napier grass. Class 1 farms applied higher levels of inorganic fertilisers, while Classes 2 and 3 had lower and the lowest inputs, respectively, of the entire nutrients. Food crops received low nutrient inputs, but commercial crops like the coffee or horticultural crops like tomatoes, had high nutrient inputs of both inorganic and organic forms. Very high negative nutrient balances were recorded under napier grass in all the farms and negative nutrient balances predominated all the classes in the three sites.

**Key words:** NUTMON, participatory learning, soil fertility

### **Effect of minjingu phosphate rock and agricultural lime on maize and legume yields on acid soils of western Kenya**

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In western Kenya, the long term development constraints have been food insecurity and poverty. In this region, with about 5 million people, cultivating nearly 0.5 million hectares of land, yields of the staple maize and legume (beans, groundnuts, soybeans and cowpeas) crops hardly exceed  $0.5 \text{ t ha}^{-1} \text{ season}^{-1}$  on smallholder farms. Low soil fertility significantly contributes to low and unsustainable food productivity in the region. On-farm field experiments were carried out at Mabanga in Bungoma District, Sega in Siaya District, Kuinet in Uasin Gishu District and Kitale in Trans Nzoia District in Kenya to test the liming and phosphate effects of some chosen materials. The biogenic, reactive, readily available and cheap Minjingu Phosphate rock (MPR; 38.3% CaO) was tested against agricultural lime (20.8 % CaO) and DAP and triple superphosphate (TSP) sources of P (at 0, 30, 60 and  $90 \text{ kg P ha}^{-1}$ ). Thus, MPR at 0, 0.25, 0.5 and  $0.75 \text{ t ha}^{-1}$  supplied the P rates above in addition to 0, 96, 192 and  $287 \text{ kg CaO ha}^{-1}$ . Similar liming rates were adopted for agricultural lime (L) used in MPR liming material comparison, while DAP and TSP sources of P supplied the same rates of P as for MPR above ( $0\text{-}90 \text{ kg P ha}^{-1}$ ). Since TSP contains some Ca (12-14% Ca), this amount was topped up to the required levels being tested in this experiment. To eliminate possible deficiency of the commonly limiting N, the highest level of  $81 \text{ kg N ha}^{-1}$  from the highest DAP rate of  $90 \text{ kg P ha}^{-1}$  was applied to all non-DAP treatments as urea, including lower ( $30$  and  $60 \text{ kg P ha}^{-1}$ ) DAP rates. Maize and soybean intercropped at the Kuinet and Kitale sites, and maize and groundnuts intercropped at the Mabanga and Sega sites, were planted during the 2005 long rains (LR) for all sites and during the 2005 short rains (SR) and 2006 LR for Mabanga and Sega sites using the staggered two maize and legume rows (the 'MBILI' system), which allows adequate radiation to reach the legumes. To monitor changes in the soil due to the effect of P and lime additions, soils were sampled every month at Mabanga and Sega sites and every two months at the longer crop

growing Kitale and Kuinet sites for pH and available P determination. Gross margins (GM), return to land, labour and capital parameters were calculated to establish the economic rate of the soil amendment materials in the different sites. Results for the 2005 LR, indicated significant ( $p < 0.01$ ) responses of both maize and legume crops to the P and soil acidity amendment materials. Orthogonal contrasts tests also showed significant differences ( $p < 0.01$ ) among the different materials in terms of crop yields. The highest maize yields were obtained from DAP in combination with lime (DAPL) at all the sites (9.39, 6.19, 5.49 and 4.52 t ha<sup>-1</sup> for the Kitale, Kuinet, Mabanga and Sega sites, respectively). The highest groundnut yields were obtained from MPR in Mabanga (0.59 t ha<sup>-1</sup>) and DAPL at the Sega (0.4 t ha<sup>-1</sup>) site. The highest soybean yields were obtained from the lime alone treatment at Kitale (0.48 t ha<sup>-1</sup>) and TSP in combination with lime (TSPL) at Kuinet (0.44 t ha<sup>-1</sup>). All soil amendments increased soil available P at all the sites, whereas soil pH was increased by materials containing CaO. There was high positive correlation between maize yields and soil available P for all the sites at the third and fourth sampling dates. Legume yields showed poor correlation with soil available P at all sampling dates for all the sites. Treatments significantly increased N and P uptake in both the maize and legume crops. Both external (agronomic) and internal (physiological) nutrient use efficiencies were highest for the DAP in combination with lime treatments at all the sites. In the second (2005 SR) and third (2006 LR) seasons, residual effects of the soil amendments was tested at the Mabanga and Sega sites. Responses to the residual effect of the soil amendments in 2006 LR showed higher yields compared to the 2005 SR probably due to the even rainfall distribution. In this season, Mabanga had yields of 5.06 and 0.61 t ha<sup>-1</sup> for maize and groundnut, respectively. Sega had yields of 2.86 and 0.44 t ha<sup>-1</sup> for maize and groundnut, respectively. MPR had better residual effect compared to TSPL, DAPL and L in terms of crop yields, soil pH and soil available P. Soil pH and available P were increased significantly.

**Key words:** DAP, groundnut, pH, soybean, TSP

### **‘MBILI’ and conventional intercropping systems in relation to root characteristics, nutrient uptake and yields of intercrops in western Kenya**

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In Kenya and most of Sub-Saharan African countries, smallholder farmers practice maize-legume intercropping. In most cases, they are assured of a legume crop in the event of inadequate rains resulting in maize crop failure. However, low nutrient levels in soils result in low yields for both crops. On farm experiments were carried out in four districts of western Kenya (Bungoma, Siaya, Trans Nzoia and Uasin Gishu in Kenya). The experiment consisted of three intercropping systems (MBILI, Hill and Conventional), maize and two legumes per site (bean with soybean or groundnut) and two fertiliser levels; 0 and 27 kg P ha<sup>-1</sup>. Soil and plant samples were taken at different stages of the experiment and chemically analyzed. Rooting patterns of intercrops were also studied. Harvesting of crops was done at maturity to determine yields and nutrient uptake. There were significant differences in the amounts of nitrate available at 0-15 and 15-30 cm depths as a result of the intercropping systems for all the sites. Higher levels of nitrate were found in the 15-30 cm depth in both Conventional and Hill intercropping systems for all the sites. MBILI intercropping had most of the nitrate in the 0-15 cm depth, thus favouring N uptake from MBILI. The legumes had no significant effect on the amounts of nitrate on the two sampling depths. MBILI intercropping had the highest root length density, while Hill

intercropping had the lowest densities in all the sites regardless of the legume planted. The highest yields for grain legumes were from MBILI intercropping with fertiliser for all the sites. Bungoma had the highest groundnut yields. This site further gave the highest bean yield under MBILI intercropping ( $1.4 \text{ t ha}^{-1}$ ) above the farmers yields of below  $0.25 \text{ t ha}^{-1}$ . Kitale gave the highest soybean yields ranging from  $180 \text{ kg ha}^{-1}$  for Hill intercropping without fertiliser to  $583 \text{ kg ha}^{-1}$  from MBILI with fertiliser. There were significant differences ( $p < 0.01$ ) in maize grain yield due to fertiliser application and intercropping systems. MBILI intercropping gave the highest maize yields ( $5 \text{ t ha}^{-1}$ ) in all the sites except Segla, while controls gave low yields ( $1 \text{ t ha}^{-1}$ ) in all the sites compared to the fertilised intercrops.

**Key words:** Beans, hill intercropping, maize, soybean

### **Effect of nitrogen and phosphorus seed yield and quality of common bean**

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Common bean is an important food and cash crop in sub-Saharan Africa. It is the cheapest source of protein and ranks third in importance as a staple food in SSA. Common bean yields in Kenya are low ( $700 \text{ kg ha}^{-1}$ ) compared to yield potentials of  $3000\text{-}5000 \text{ kg ha}^{-1}$ , mainly due to low soil fertility, Aluminium and Mn toxicities. The aim of the study was to determine the effects of N and P on seed quality and yield of common bean. The study consisted of three field experiments in a 4 by 4 factorial experiment arranged in a randomised complete block design with 4 levels of N as CAN and 4 levels of P as TSP (16 treatments) conducted in Uasin Gishu, Busia and Siaya districts, respectively. The trials were carried out for one season (Uasin Gishu, long rains; Busia and Siaya, short rains). Soils (0-15 cm depth) in the three sites were acidic ( $\text{pH} < 5.5$ ). The soils were generally deficient in N and P, adequate in Ca and Mg, and crop uptake of N and P depended on the initial soil N and P contents, coupled with N and P fertiliser inputs. Application of N and P was significant ( $p < 0.05$ ) together with N and P uptake, growth in height, trifoliolate leaves, pods per plant, dry matter yield and seed yield. However, seed purity, vigour viability and moisture content were not significant.

**Key words:** Nutrient uptake, *Phaseolus vulgaris*, seed vigour

### **Effectiveness of PRE-PAC on nutrient uptake and yields of maize-legume intercrops in a ferralsol of western Kenya**

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Sub-Saharan Africa continues to experience food insecurity. Western Kenya contains 40% of the country's population on only 15% of the country's land area, with population densities ranging from 500 to 1200 persons per  $\text{km}^2$ . Towards achievement of food security, "PREP-PAC", an integrated nutrient management package was developed as a simple, effective and affordable package that can be adopted by resource poor farmers. PREP-PAC contains 2 kg Minjingu phosphate rock, 0.2 kg Urea, 120 g legume seed, Rhizobium seed inoculant, seed adhesive and lime pellets, which are intended to ameliorate low fertility in  $25 \text{ m}^2$  area. PREP-

PAC was tested in this study, for its diversity on intercrops on small scale farm in Nyabeda, Siaya District in western Kenya, for three consecutive cropping seasons. MBILI (one row of cereal crop alternating with two rows of legume) system involving seven legumes, intercropped with maize (*Zea mays*) was used. The legumes included soybean (*Glycine max*), Bambara nuts (*Voandzeia subterranean*), cowpea (*Vigna unguiculata*), Groundnut (*Arachis hypogea*), Yellow gram (*Phaseolus aureus*) and Dolichos bean (*Lablab purpureus*). The results showed significant increases in soil pH and available P ( $p < 0.01$ ) due to PREP-PAC application under MBILI intercropping system, PREP-PAC under MBILI intercrops and their interaction with seasons gave a significant ( $p < 0.01$ ) increase in maize grain yield, with maximum mean increases of  $2,002 \text{ kg ha}^{-1}$  above the control. Legume grain yields, ranging from 52 to  $866 \text{ kg ha}^{-1}$ , varied with the cropping season, maize-legume intercrops, legume species and PREP-PAC application. The use of PREP-PAC under MBILI system generally increased the physiological P use efficiency (PPUE) in maize and legumes. Overall, PPUE was highest, with 26.5 and 6.2 kg increases in grain kg P uptake for maize and legumes, respectively. Economically, the net change in profit was significantly ( $p < 0.01$ ) increased due to PREP-PAC under MBILI intercropping system, whereby, maize-yellow gram intercrop gave the highest value of Kenya shillings (Kshs.)  $89,706.17 \text{ ha}^{-1} \text{ yr}^{-1}$  and maize-Bambara nuts the least with Kshs.  $25,236.90 \text{ ha}^{-1} \text{ yr}^{-1}$ , above the control.

**Key words:** Groundnut, Mbilli, nitrogen, phosphorus, soybean

### **Use of amendments to improve yields of tea grown in strongly acidic soils in Kenya**

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A study to find out whether the use of soil amendments, lime, gypsum, and phosphorus fertiliser could counteract strong soil acidity and improve nutrient uptake and, ultimately, the yield of moribund tea, *Camellia sinensis*, (old teas which do not give yield response to other cultural inputs); or clonal tea grown on soil from a moribund tea field was undertaken. A potted plant trial compared the effects of the soil from a moribund tea field with that from a nearby virgin forest area, on the growth of three clones of tea. Two other potted plant trials lasting two years, evaluated the effects of lime, magnesium and phosphorus fertilisers on the growth of one of the clones under the soil from a moribund tea field. Application of lime increased calcium content in the feeder roots, while application of magnesium increased magnesium content in all the plant tissues and also the feeder roots dry weight. The effects of the three treatments on the moribund tea yield were variable. Compared to the plants grown under the soil from the moribund tea, those under the forest soil showed increased uptake of both calcium and magnesium, decreased uptake of manganese and higher leaf and fine root dry weights. Application of lime to the soil from the moribund tea field increased phosphorus, calcium and magnesium uptake, but decreased manganese and aluminium uptake by the tea plants. Magnesium fertiliser increased magnesium, but decreased manganese uptake by the tea plants. Combining lime with magnesium fertiliser decreased plant growth linearly, while combining lime with phosphorus fertiliser increased the growth.

**Key words:** Calcium, *Comellia sinensis*, lime, magnesium

### **Farm-level economics and adoption of soil conservation in Nyando River Basin in Kenya**

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Soil conservation practices need high investments, yet benefits take long to be realised. Most farmers abandon conservation measures once agents promoting them withdraw their support. Previous research shows that conservation programmes have been launched without careful evaluation of socio-economics of adoption of the technologies. The objectives of this study were to (i) make economic evaluation of soil conservation techniques; (ii) determine optimal cropping patterns that meet families' main goals, and (iii) analyse factors affecting both adoption and decision to continue with soil conservation once financial and technical support ceases. A multistage sampling procedure was used to collect cross-sectional data from households. A random sample of 200 farmers was selected from three divisions of Kericho district in Kenya. Questionnaires administered in the area provided primary data needed for analyses. Secondary data were also used in the study. Gross margin and cost-benefit analyses were used to evaluate the adoption process for the technologies. Econometric models were used to analyse factors affecting adoption of soil conservation technologies. The results indicated a significant profitability difference between promoted soil conservation measures. The goal-programming problem indicated that out of 20 basic cropping activities identified in the study area, 4 entered the programme. Most variables postulated to affect adoption were found significant in determining initial and continued adoption of soil conservation measures. Profitability differences between the promoted technologies, farm, farmer, technology and institution factors should be considered in technology promotional strategies in the study area.

**Key words:** Cost benefit, gross margin, profitability

### **Influence of surface water management and fertiliser use on growth and yields of maize in vertisols of Kenya**

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Food security is one of the corner stones for developing a stable and prosperous nation. However, in recent years, Kenya has experienced frequent shortages of staple food crops, among them cereal grains including maize, wheat, rice, due to inadequate production occasioned by frequent droughts and other constraints. Consequently, the country now imports significant quantities of the food grains annually. Further, an increasing proportion of the population relies on relief food aid due to fluctuations in the food production and eroded economic base. Soil fertility depletion is one of the root causes of declining food production in Sub-Saharan Africa, hence, increased food security risk in the region. Thus, there is urgent need to reverse the downward trend in the food production and increase land productivity. In that regard, development and application of technologies, which restores and maintains the soil fertility for sustainable land management, is the only way to ensure food security in the region. It is my sincere hope that this work has contributed to advancement of the scientific and technological

knowledge so urgently required in addressing issues pertinent to sustainable food production and security in the country.

**Key words:** Drought, rice, soil fertility, wheat

### **Effect of organic and inorganic phosphorus sources on soil chemical properties and maize yield in acid soils of western Kenya**

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Phosphorus deficiencies and Al toxicities, which often occur simultaneously in acid soils in western Kenya can be mitigated by the use of P fertilisers and lime. This strategy has, however, not been effective among the smallholder farmers due to its high cost. Other cost-effective strategies, therefore, need to be explored. This study tested the effect of two organic materials (OMs) of varying chemical characteristics, i.e., farmyard manure (FYM) and *Tithonia diversifolia* (tithonia), on maize (*Zea mays*) yields when applied alone or in combination with three inorganic P sources, i.e., triple super phosphate (TSP), Minjingu Phosphate Rock (MPR) and Busumbu Phosphate Rock (BPR) at Kakamega and Bukura in Kenya. The effects of these P sources on selected soil chemical properties were monitored in a laboratory incubation study, greenhouse pot study and field experiment. FYM, tithonia and MPR increased soil pH and reduced the exchangeable Al in the short-term. TSP was the most effective in increasing the Olsen P in soils, while BPR was the least effective. There was no evidence of synergism in terms of increased Olsen P when organic and inorganic P sources were combined. None of the treatments significantly affected P sorption by soils at Kakamega. However, at Bukura, lime in combination with TSP was the most effective in decreasing P sorption followed by FYM applied in combination with TSP. Inorganic P fractions were significantly affected by the treatments, but the organic fractions were not. The NaOH (organic and inorganic P) fraction was dominant at Bukura. Overcoming P deficiency without elimination/reduction of exchangeable Al did not increase P uptake by maize. Similarly, reduction of exchangeable Al without a corresponding application of P, failed to increase the uptake. Once the effect of Al toxicity on plant growth was reduced by application of the OMs or lime, the maize grain yield and P uptake increased with increasing available soil P. Tithonia applied alone, or in combination with inorganic P sources, was more effective in increasing maize yields than any other treatments at similar P application rates. Although FYM was more effective than tithonia in reducing the P sorption capacity of the soil and increasing the available soil P, it consistently gave lower yields than tithonia, suggesting that the ability of an OM to lower the exchangeable Al in soils is more important, in terms of increasing maize yields, than its ability to increase soil P availability. MPR applied with urea was superior to TSP combined with urea in increasing maize yields at Bukura in the three seasons. Despite giving high maize yields, the tithonia treatments had very high labour costs, which led to low value cost ratios, thus, casting doubts on the potential for adoption of the tithonia biomass technology in western Kenya.

**Key words:** Farm yard manure, Minjing phosphate, Tithania

### **Use of organic and inorganic fertilisers to replenish nitrogen and phosphorus in smallholder farms in tropical Africa agriculture**

Kisinyo, P. O., Othieno, C. O., Okalebo J. R., Opala, P. Osiyo, R. J. Kipsat, Serem, M.A. and Maghanga, J. K.  
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A major cause of declining food production in smallholder tropical Africa is soil-fertility depletion, especially nitrogen and phosphorus. It is estimated that 792 kg N and 98 kg P ha<sup>-1</sup> have been lost between 1967 and 2006 from about 200 million ha cultivated land in 37 African countries. Soil nutrient capital is the stocks of N, P and other essential elements that become available to plants during a time scale of 5 to 10 years. Population increase has caused continuous cultivation, replacing traditional African long-term fallows, which maintained soil fertility, thus, necessitating inorganic fertiliser use. Small-scale farmers appreciate inorganic fertilisers (IM), but seldom apply the recommended rates due to high costs, lack of credits and variable returns. Therefore, the goal should be supplying most nutrients through organic materials (OM) and making up the short fall through IM. Combined use of organic-inorganic materials aims at synchronising crop nutrient demand while minimising N losses. Soil organic matter increases P-availability by reducing soil P-sorption capacity and improves soil physical characteristics. Benefits of combined organic-inorganic nutrient use on soil fertility have been shown, yet there are no guidelines for their management due to lack of information on: OM quantities available, mathematical models adequately showing combined usage and inadequate amounts available.

**Key words:** Nitrogen, phosphorus, soil fertility depletion

### **Organic and inorganic nitrogen sources and phosphorus fertiliser application methods: An agronomic and economic assessment in western Kenya**

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Simultaneous deficiencies of nitrogen and phosphorus, which limit crop production in western Kenya can be overcome through a combined application of organic and inorganic fertilisers. An experiment was conducted with maize (*Zea mays*) to compare two methods of application of inorganic P fertiliser (broadcast *versus* spot) in a factorial combinations with three N sources, i.e, farmyard manure (FYM), *Tithonia diversifolia* (green manure) and urea. Net financial benefits of the tested practices were computed using partial budgeting. There was no significant ( $p>0.05$ ) interaction between the P fertiliser application method and the N source. Maize yield was not significantly influenced by P fertiliser application method or N source. FYM integrated with P fertiliser, applied using the broadcast method, had the highest cumulative net benefits and was, therefore, the most economically attractive input combination.

**Key words:** Farm yard manure, net benefit, *Tithoria*

### **Effect of organic materials on Minjingu rock phosphate in acid soil of western Kenya**

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This study evaluated the effect of organic materials on Minjingu rock phosphate (MPR) in acid soil obtained from Bumala in western Kenya. Farm yard manure (1% P), poultry manure (1.8%P), maize stover (0.75%P), and tithonia leaves (2.7%P) were ground before incubation with MPR at the rate of 2 t ha<sup>-1</sup> in a 2 kg soil. The organic materials were thoroughly mixed with soil containing MPR at the rate of 20 kg ha<sup>-1</sup>. Extractable P was determined using Olsen method. All the organic materials significantly increased ( $p < 0.05$ ) extractable P. However, poultry manure and farm yard manure had a greater increase in extractable P than tithonia leaves or maize stover. These results show that high quality high quality organic materials have a potential of increasing P availability from MPR in the field. Therefore, the shortage of P in Bumala soil can be reversed if farmers prepare and apply good quality manure together with MPR. Such manure can be obtained by improving the methods of preparation and storage to reduce nutrient loss. Maize stover generated in substantial quantities can also be combined with MPR to increase P availability. However, the residue should either be composted before application or primed to reduce immobilisation of soil P upon application with MPR.

**Key words:** Organic materials, P availability, quality

### **Response of maize-bean intercrops to Minjingu phosphate rock and lime in terms of nutrient use efficiency and economic benefits on acid soils of western Kenya**

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The benefit of liming highly weathered, low P-testing acid soils of western Kenya has been neglected. We tested simultaneously, the liming and phosphate effects of the biogenic, reactive, readily available and cheap Minjingu Phosphate Rock (MPR); (38.3% CaO) against another cheap and available agricultural lime (20.8% CaO), and the widely used DAP as source of P (at 0, 60, 120 and 180 kg P ha<sup>-1</sup>). The MPR at the above P rates supplied 0, 0.2, 0.4 and 0.6 t ha<sup>-1</sup> CaO, respectively. Similar liming rates were adopted for agricultural lime (L) used in MPR liming material comparison. To eliminate possible deficiency of the commonly limiting nitrogen, the highest level of 160 kg N ha<sup>-1</sup> from the highest DAP (or P rate) of 180 kg P ha<sup>-1</sup> was applied to all non-DAP treatments as urea (including lower DAP rates). Maize and beans were planted using staggered two maize and bean rows. Treatments significantly ( $p < 0.05$ ) increased both maize and bean yields. MPR and DAP+L treatments gave the highest maize yields; 5.67 and 6.24 t ha<sup>-1</sup>, respectively compared to 0.48 t ha<sup>-1</sup> in the control for maize and 0.93 and 0.86 t ha<sup>-1</sup>, respectively compared to 0.28 t ha<sup>-1</sup> in the control for beans. Increased external P use efficiency; 10.9, 9.6 kg grain kg<sup>-1</sup> P for beans and 82.4, 91.7 kg grain kg<sup>-1</sup> P for maize was obtained for MPR and DAP+L, respectively, at the lowest P rate (60 kg P ha<sup>-1</sup>). Highest N use efficiency, 34 and 4.05 kg grain kg<sup>-1</sup> N for maize and beans, respectively was associated with the highest DAP+L rates (180 kg P ha<sup>-1</sup> and 0.6 CaO t ha<sup>-1</sup>). The treatments further raised the crude protein contents

of both maize and bean grains. The single factor ANOVA on profitability indicated a significant probability difference at 95% confidence interval between the considered acid soil ameliorants. All in all, both MPR and Lime are effective liming materials in western Kenya.

**Key words:** Agricultural lime, DAP, nitrogen, phosphorus

### **Effect of row arrangement and fertility inputs on the yield of maize and legume intercrops in semi-arid region of eastern Kenya**

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Managing Beneficial Interactions for Legume Intercrops (MBILI) technology was developed over a rather limited set of soils and climatic conditions and, hence, there was need to extend it to a wider range of agro-ecological conditions. The objective of this work was to test and refine the technology under small-scale farm conditions of semi-arid parts of eastern Kenya. Treatments consisted of two intercropping systems (MBILI and conventional) of maize and different legumes (beans, cowpeas and green grams), with or without a combination of 10 tonnes farmyard manure (FYM), 20 kg P<sub>2</sub>O<sub>5</sub> and 20 kg N ha<sup>-1</sup>. Farmer-field-day results indicated that 73% of the participants preferred MBILI technology because it had fewer incidences of aphids on cowpeas, allowed more light penetration to the legumes and showed signs of better soil moisture retention. Significant (p<0.05) grain yield increases above control were obtained under MBILI arrangement with combination of FYM, 20 kg P<sub>2</sub>O<sub>5</sub> and 20 kg N ha<sup>-1</sup> in maize (41% and 101% in short and long rains of 2004) and bean (48%) in the long rains. In the maize + cowpea intercrops, higher maize yields were obtained under conventional compared to MBILI arrangement, irrespective of the fertility input. A combination of MBILI arrangement and fertility input is preferable to farmers interested in optimizing both maize and beans production in the semi-arid regions.

**Key words:** MBILI, *Phaseolus vulgaris*, *Zea mays*

### **Towards improved agricultural productivity in africa: A report on global concerns**

Okalebo, J.R.

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The known worldwide constraints of food insecurity, poverty and poor health, largely threaten human survival and development, particularly in the sub-Saharan Africa (SSA). Substantial efforts have been made to mitigate these constraints in the region. However, among multiple reasons contributing to the above problems, the low and unsustainable agricultural productivity is frequently explained in terms of the deteriorating capacities of soils to supply nutrients needed for healthy and productive crops (including livestock). The soils in SSA have widespread nitrogen and phosphorus deficiencies. Arising from these constraints, global concerns were

presented and shared in two international fora in 2006. Development highlights and suggested ways forward are summarised here. The third International Symposium on Phosphorus Dynamics in a Soil-Plant Continuum, held in May 2006 Brazil, reviewed progress on P soil testing and enhanced P availability, focusing on the rhizosphere processes, including progress in maize breeding towards P acquisition in acid soils (the success stories from EMBRAPA, Brazil and CIMMYT in Mexico). Brazil currently practices minimum to no tillage in their farming systems, giving maize yield up to 10 t ha<sup>-1</sup>, and soybean yield of 4 t ha<sup>-1</sup>. The second forum convened in Oslo, Norway in August/September 2006, addressed the issue of African Green Revolution as a guideline for achieving food security and reduced poverty in Africa. The private sector, scientists donors and policy makers (among others) participated at this YARA International Conference. Pertinent issues were the reviews of developments and achievements from private sector and donor projects being executed in Africa in line with the Millennium Development goals. Thus, the declining cocoa production in Ghana is being reversed under the Mars private sector collaboration in USA. Women are leading CBO based projects in Kenya (Maseno area), Uganda (Victoria Seed Company) and Mozambique; while Technoserve is promoting cotton production in Tanzania. Overall, development tasks are being tested in Bar-Sauri village in western Kenya. Some suggested way forward are: Targeted research and transfer of science and technology to farmers; access to finance to allow development of farming and the surrounding infrastructure; linking of production to output markets to facilitate appropriate production choices including value addition; the value of crop diversification in optimizing farmers returns and understanding of principles of risk management to protect those returns.

**Key words:** Agriculture, depleted soils, private sector, sustainability

### **Tolerance of selected common bean cultivars to phosphorus deficiency seed production**

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Common beans (*Phaseolus vulgaris* L.) are an important source of protein for most households in Kenya. Their production is, however, constrained by inadequate soil phosphorus. However, because bean cultivars vary in acquisition and utilisation of limited soil phosphorus, selection of cultivars tolerant to phosphorus deficiency would improve production on soils low in available phosphorus or where farmers are too poor to apply P fertilisers. The status of tolerance to P deficiency in Kenyan common bean has not been studied. Seventy seven local common bean accessions were tested for growth in low-P (2 mg kg<sup>-1</sup>) soils and compared to growth in P-supplemented (64 kg P ha<sup>-1</sup>) soils. Phosphorus fertiliser significantly increased seed weight per plant in most bean accessions, from a low mean of 2.98 g to a mean high of 13.42 g. Accessions such as Bus 6i, Bus 6n, Mig6 and Bus 6u had significantly higher seed production under low soil phosphorus compared to others. These accessions shall be subjected to field tests and the physiological mechanism of tolerance to P deficiency shall also be investigated.

**Key words:** Low phosphorus, *Phaseolus vulgaris*, seed weight

### Genetics of tolerance to aluminium in maize lines in Kenya

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The average maize yield in Kenya is only 2 t ha<sup>-1</sup> and the crop is mainly grown in acid soil regions. Development of maize cultivars with tolerance to soil acidity can alleviate this problem. Aluminium tolerance in roots of crosses involving two tolerant and one susceptible inbred line, were studied using intact roots of maize seedlings grown in a nutrient solution (222 µM Al) at controlled pH (4.2) and temperature (26 °C). Inbred line Al 237/67 had the highest root growth, while Reg00114 had the lowest. Back crosses involving the susceptible parent showed the least root growth. The F<sub>2</sub>s generally had less root growth compared to the F<sub>1</sub>s for the crosses used. Additive variance was more preponderant compared to dominance variance in the inheritance of aluminium tolerance and it contributed 66 and 82% of the total genetic variance in the two crosses studied. The number of genes for aluminium tolerance was about 8 and 4 for the first and the second crosses, respectively. Additive genetic effects were significant and positive for both crosses signifying an enhancing effect in the inheritance of aluminium tolerance. Tolerance in inbred G and R11C7-44 is quantitatively inherited. Additive gene effects were more predominant than dominance gene effects.

**Key words:** Genetic variance, root growth, susceptible parents

### Contribution of phosphate rocks on soil fertility restoration in the depleted soils of western Kenya

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Most sub-Saharan African countries continue to have slow development rates, mainly as a result of food insecurity, poverty and poor health of the human populations, made worse by the prevalent HIV/AIDS pandemic. In relation to food insecurity, plant nutrients, nitrogen and phosphorus are predominantly deficient in the highly weathered and leached soils such as those of western Kenya. Hence, the low inherent nutrients in soils, together with nutrient mining in crop harvests, contribute to the well-known low and declining crop yields in this region. Substantial efforts have tested the use of the widely distributed phosphate rocks in SSA, with an overall objective of restoring the P status of the soils. Thus, in the highly populated (50-1200 person ha<sup>-1</sup>) western Kenya, the direct application of the reactive Minjingu (Tanzania) PR blended Busumbu phosphate rock (PR) with soluble triple superphosphate (TSP) at rates from 20 to 250 kg P ha<sup>-1</sup>, have resulted in significant maize yield increases from

below 0.5 t ha<sup>-1</sup> season at smallholder farm level to 4-5 t ha season<sup>-1</sup>. The PR tested compares favourably with TSP in relation to maize and legume yields. In spite of these demonstrations on the effectiveness of PR, the small-scale farmers hardly adopt improved technologies.

**Key words:** Maize legume, soil fertility depletion, TSP

### **Effect of phosphorus sources on early growth, nodulation and nitrogen fixation by agroforestry species in western Kenya**

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An experiment was conducted to evaluate the effects of east African phosphate rocks (Busumbu and Minjingu) and triple superphosphate (TSP) on soil total N and available P growth, nodulation and N fixation of *Crotalaria grahamiana*, *Sesbania sesban* and *Tephrosia vogelii*. The three P sources had a positive effect on the parameters studied, but Minjingu PR had the greatest effect. Although not as effective as Minjingu PR or TSP, in some parameters studied, Busumbu PR was better than control (no P) treatment and was as effective as TSP in enhancing soil available P, soil total N and N fixation, as reflected in plant total N. There is need to rigorously evaluate and explore ways of improving the efficiencies, including monitoring the residual effects of local PRs, particularly Busumbu PR, whose source is closer to the target areas in western Kenya.

**Key words:** Agroforestry, Busumbu, *Crotalaria*, Mirijingu, *Sesbania*, *Tephrosia*

### **Effect of organic materials and rock phosphate on phosphorus availability and maize yield in acid soils of western Kenya**

Osiyo, J.O.R., Othieno, C.O., Kisinyo, P.O. and Okalebo, J.R.  
Moi University, Kenya

Phosphorus is critically needed to improve soil fertility for higher crop production in western Kenya. The high cost of conventional water soluble P fertilisers constraints their use by resource – poor farmers. Use of soluble P fertiliser is further complicated by high P fixation by the acid soils of western Kenya. This study determined the effect of maize stover, farm yard manure (FYM) and Minjingu, phosphate rock (MPR) on soil pH and P availability in orthic Ferralsols of Siaya District in western Kenya. MPR and the organic material applied separately or combined reduced soil pH. The Extractable P values increased significantly ( $p < 0.05$ ) above the control in treatments where MPR and organic materials were applied separately. Combining MPR with organic materials increased P availability compared to control plots. However, the quality of organic material determined magnitude of P availability. FYM increased P levels better than maize stover. Combined FYM and MPR were better than MPR and maize stover. Hence, farmers can consider improving quality of FYM to combine with MPR to improve P availability. Yield increases were highest with FYM and MPR combined. Although the study was done where MPR might not be cheaply available, the technology can be used in areas with rock P deposits.

**Key words:** Minjingu phosphate rock, phosphorus availability

### **Effect of fertilisation on stalk-diameter ratio and yield of maize in Siaya, western Kenya**

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In an experiment carried out at Sauri sub-location, Siaya district, in Kenya, the growth analysis method was used to examine the effect of N, P and K fertilisation on maize growth dynamics. Nonlinear mixed-effects modeling approach was used to model height-diameter ratio of the maize stalk in conjunction with fertiliser treatments. Comparisons of treatments effects over time were integrated with the model-building process. The rate of growth estimated values of the maize were the most important in correlating grain yield; ( $r=0.60$ ,  $p=0.025$ ). Maize stalk slenderness (height-diameter ratio) were significantly different for K, N+K, N+P and N+K+P, suggesting that nutrient enrichment influenced the resource allocation pattern such that both height and diameter growth were favoured. The growth response for P, P+K and N treatments were higher than the control, though not significant ( $p>0.05$ ). The difference in steepness of the curves and the maximum attained a asymptotic value of the maize mean stalk slenderness (height-diameter ratio), were used to measure plant performance in relation to the nutrient applied. Height-diameter ratio relates to a higher mechanical safety and a better biological supply with water and assimilates to plants.

**Keywords:** Height-diameter ratio, nitrogen, phosphorus, potassium

### **Quantitative evaluation of low input technologies and adoption levels in western Kenya**

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and Kosgey, R.C.

Moi University, Kenya

Soil fertility depletion in western Kenya is a major concern because it is linked to hunger and poverty in the region. Various research organisations continue to develop technologies to replenish soil nutrients, especially nitrogen and phosphorus and raise pH of the acidic soils. This study involved evaluation of low cost soil fertility replenishment technologies developed for western Kenya in the last ten years and their level of adoption. A questionnaire was used to interview farmers and key informants. The technologies improved crop yields in all the sites, but most farmers abandoned them soon after the projects ended. All the technologies lacked in-built dissemination procedures and did not involve the local extension officers. In some cases, researchers got information they required and abandoned the farmers. Major obstacles to technology adoption were lack of capital, high level poverty, ignorance and poor follow up by extension agents. Future research should in-build dissemination procedure involving extension officers. Farmers could be given initial capital in form of inputs such as seeds and chemicals along with technical advice.

**Key words:** Low cost, maize, soil fertility

## **Short-term effects of organic residues and urea on maize productivity in western Kenya**

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The use of organic materials in combination with inorganic fertilisers to optimise nutrient availability to plants is a difficult task as organic materials have variable and complex chemical nature. This requires the understanding and knowledge about the chemical composition, particularly the nutrient content and C quality of organic materials and their (organic materials) interaction with inorganic nutrient sources. Unfortunately, there has been little synthesis of the integrated effects of organic materials on net nutrient management. The effect of integrated use of urea and calliandra or maize stover on yield and N uptake of maize was assessed in two soil types in western Kenya. Urea and calliandra or maize stover were combined in a way to supply N at 75 kg ha<sup>-1</sup> from both sources in 0:0, 100:0, 80:20, 60:40, 40:60, 20:80, 0:100 ratios. Maximum total yield was obtained in T2 receiving N from the two sources in 80:20 ratios. The yields were significantly ( $p < 0.05$ ) lower in treatments where N from urea was below 50%. Similarly, the N uptake in grain, stover and cobs was significantly greater in treatments receiving 80 or 60 % N from urea and 20 or 40% N from calliandra or maize stover, respectively. Thus, integrated use of urea, calliandra or maize stover at 80:20 or 60:40 ratios (N basis) produced maximum yields and is, therefore, recommended for profitable maize yield and sustainable soil fertility. Integrated use of urea and calliandra or maize stover performed better than urea, calliandra or maize stover alone. The recombined application of urea and calliandra at 80:20% or urea and maize stover at 60:40% ratio based on the net N contribution produced excellent results and are, therefore, recommended for use by small scale farmers for maize production.

**Key words:** Nitrogen uptake, urea, use efficiency

## **Response of soybean to sources of phosphorus on acidic soils of Kapsabet, Kenya**

Kebeney, V. and Okalebo, J.R.

Moi University, Kenya

Soil nutrient depletion poses a serious threat to the welfare of the small scale farmers in Africa. The deficiency of phosphorus and nitrogen in most Kenyan soils, for instance necessitates attention and must be addressed in any strategy to increase crop production. This study investigated the response of soybeans (*Glycine Max. L*) to application of two phosphorus sources, diammonium phosphate (DAP) and Minjingu Phosphate Rock (MPR). A pot experiment was installed at Moi University containing soils of Kapsabet, Kenya. The sites soils were slightly acidic (pH 5.02), with low available P, low N content and low organic carbon. Soybeans treated with DAP showed vivid purple colouration on the older leaves, and slender stems indicating P deficiency in the soils. Those treated with MPR showed excellent performance, especially at 40 kg h<sup>-1</sup>. MPR helps reduce soil acidity, thus, improving the crop performance through its dissolution effect.

**Key words:** Diammonium phosphate, Minjingu phosphate rock

### **Response of maize and beans intercrop to phosphorus and lime in acidic soils of Uasin Gishu District, Kenya**

Nauvuana, S. and Okalebo, J.R.  
Moi University, Kenya

Nitrogen and phosphorus are the most limiting nutrients to crop production in Uasin Gishu district, Kenya. Phosphorus immobilisation often occurs as a result of unfavourable pH levels that render phosphorus unavailable to crops, through iron and aluminium fixation. The objective of the study was to determine the response of maize (*Zea mays* L) and rose coco bean (*Phaseolus vulgaris*) to phosphorus and lime applications. A field study was conducted on acidic soil at Kuinet area in Uasin Gishu district. It comprised of control treatment, Lime alone (L), Maize stover with Lime (MS+L), Diammonium phosphate with Lime (D+L), maize stover plus diammonium phosphate with Lime (MS+D+L). D+MS+L treatment showed the highest maize grain yield of 0.89 t ha<sup>-1</sup> (p<0.05). But this was statistically comparable with MS=L, D+L and L. Bean grain yield was highest in D+L at 0.86 t ha<sup>-1</sup> and was significantly different (p<0.05) from the other treatments. Generally, nitrogen uptake values for bean grain were higher than that of maize grain. A slight increase in phosphorus uptake was evident in bean grain in comparison with maize grain. Soil pH increased from 5.50 to 5.80, with MS+L giving the highest value. Available phosphorus in soil increased from 9.94 to 15.00 mg kg<sup>-1</sup> with D+L giving the highest value. Soil nitrogen was highest in treatment L, although the nitrogen levels decreased slightly from 0.17 to 0.14. Soil carbon increased slightly from 2.13 to 2.17 with MS+L giving the highest value.

**Key words:** *Phaseolus vulgaris*, phosphorus availability, *Zea mays*

### **Effect of *Markhamia lutea* woodash on soil pH, available phosphorus and performance of *Sesbania sesban* seedlings**

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Wood is the main source of fuel to rural households in sub-Saharan Africa, which results in considerable amounts of wood ash. *Markhamia lutea* is an important wood fuel tree species in western Kenya and experience from Mumias District shows that wood ash from fireplaces is scattered on the farmlands improves the soil productivity. Wood ash is known to increase soil pH and add nutrients into the soil particularly phosphorus and potassium. The objective of this study was to determine wood ash application levels for optimum pH and phosphorus availability for *S. sesban* growth. The study was carried out at a weakly acidic ferralsol (pH 5.7) collected from western Kenya. A constant portion of the soil was treated with varying amounts of wood ash from *M. lutea* which was then potted after which *S. sesban* seeds were sown. Wood ash increased pH and improved P availability in soil conditions which improved seedling growth considerably. There was significant (p<0.05) difference in soil pH between the different levels of wood ash applications (p=0.000). There was significant difference in the amount of available P at the various levels of wood ash applications (p=0.000). There was also significant difference in dry weights of seedling between the various levels of wood ash applications (p=0.000). Wood ash at 300 t ha<sup>-1</sup> gave optimum pH and available P for best performance of *S.*

*sesban* seedlings. *Markhamia lutea* wood ash serves the dual purpose of moderating soil pH, and available P, especially in areas where the soil is acidic like western Kenya.

**Key words:** Acidic soils, *Markhamia lutea*, *Sesbania sesban*

### **Potential of increased soybean production in Uasin Gishu district resulting using Minjingu phosphate rock and agricultural lime**

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In Kenya, soil acidity is a major contributor to declining soil fertility and 20% of the soils are acidic and are considered to be of low fertility. Most farmers are unaware of the benefits of liming acid soils and, hence, blame seed and fertilisers for low yields. A study was carried out at Kuinet in Uasin Gishu District in Kenya to delineate the effects of Minjingu phosphate rock (MPR) and agricultural lime as liming materials on yields of soybean intercropped with maize. Maize responded to application of soil amendments with the diammonium phosphate + lime (DAPL) treatment giving the highest maize yields of 6.19 t ha<sup>-1</sup> compared to the control, which gave 1.36 t ha<sup>-1</sup>. Soybean yields were disappointingly low with the DAPL and control treatment (0.32 t ha<sup>-1</sup> and 0.14 t ha<sup>-1</sup>, respectively). This, however, changed significantly after the variety was changed in the second season, with yields going up to 0.68 t ha<sup>-1</sup> for the TSPL treatment.

**Key words:** Liming, soil acidity, soil fertility

### **African green revolution: Will it become a reality, particularly in Sub-Saharan Africa?**

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Sub-Saharan region (SSA) continues to experience problems of perennial hunger, poverty and poor health of its people. Agricultural production has remained low over decades and it is even declining to miserable low maize (staple) yields below 0.5 t ha<sup>-1</sup> season<sup>-1</sup> at the smallholder farm scale. Constraints contributing to low productivity are numerous, but the planting of poor quality seed, declining soil fertility, poor markets and value addition to products, frequent incidences of malaria and HIV/Aids pandemic, significantly contribute to poor productivity. Technologies to improve and sustain agricultural production are numerous as a result of extensive research and extension messages in SSA. But, technology adoption rates have been extremely low to none. Here, we highlight bottlenecks for achievement of a green revolution in Africa. Success efforts are reported, but we moot a focus on efficient utilisation of abundant

and affordable African natural resources, such as phosphate rocks to replenish depleted phosphorus in soils. But we feel that to achieve African Green Revolution, partnerships with concerned global communities, national institutions, including universities, NGOs, CBOs and farming communities need initiation and strengthening. Specifically, human capacity at all levels should be built through training. Without private sector strong participation on acquisition of inputs and marketing product, it will be difficult to achieve the dreams.

**Key words:** Food security, partnerships, poverty alleviation

### **Use of PREP-PAC product to improve maize and legume yields for improved farm income in the nutrient depleted soils of western Kenya**

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Western Kenya has 40% of the country's population on only 15% of the country's land area, with population densities ranging from 500 to 1200 persons per km<sup>2</sup>. This has resulted in reduced land sizes, continuous cropping with no addition of fertilisers due to rising poverty levels, high rates of nutrient depletion and food insecurity. 'PREP-PAC', an integrated nutrient management package that targets replenishment of 'lost' nutrients in the widespread low fertility patches, is a simple, effective and affordable package that can be adopted by resource poor farmers. PREP-PAC was tested on a small scale farm in Siaya District in western Kenya. The farm was characterised by low pH (5.35), low carbon content (1.84), Olsen P (1.12 mg P kg<sup>-1</sup>) and low total nitrogen (0.27%). It was classified as sandy clay loam (FAO classification). MBILI intercropping system involving seven legumes, intercropped with maize (*Zea mays*) was used. PREP-PAC application significantly ( $p < 0.01$ ) increased legumes and maize grain yields. A significant increase ( $p < 0.01$ ) in legumes heights five weeks after planting was reported. Economic analysis indicated a significant ( $p < 0.01$ ) increase in farm income.

**Key words:** Economic benefits, MBILI intercropping

### **Effect of integration of organic and inorganic sources of nutrient on maize yield in central Kenya**

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Low soil fertility is one of the major constraints to food production in the central highlands of Kenya. This phenomenon calls for intervention in order to fight food insecurity in this densely populated part of Kenya. Majority of the farmers use old recommendations, which were general for central Kenya, while other meander in the maze of guessing depending on crop performance

or availability of manures or fertilisers. An experiment was set up in two districts of central Kenya; Kirinyaga (Mukanduini Village) and Maragua (Kariti secondary school). Treatments consisted of manure of single application and manure in combination with varying rates of nitrogenous fertilisers. Application of manure alone at 5 t ha<sup>-1</sup> was not sufficient for high crop performance, although higher yields above the control were reflected; but on addition of nitrogen higher yields were obtained even at the lowest rate of 20 kg N ha<sup>-1</sup>. Nitrogen response curves showed that application of manure at 5 t ha<sup>-1</sup> and N in form of calcium ammonium nitrate up to 40 kg N ha<sup>-1</sup> gives yield increases.

**Key words:** Calcium ammonium nitrate, soil fertility

### **Modelling application for soil and water management for maize production in the drylands of eastern Kenya**

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The traditional field experiment approach (on-station or on-farm) is becoming inadequate in addressing problems related to complex agricultural systems. The conventional methods of experimentation, where multi-location trials are conducted over several years, are both time-consuming and expensive. One practical and cost-effective alternative is to use simulation models. Models enable effective investigation of a wide range of production scenarios over varying climatic and soil conditions. Over the past two decades, the crop growth modeling approach using dynamic process models, has been adopted in Kenya to address problems related to effective and efficient management of natural resources. This paper provides a review of CERES-maize model adaptation and application for maize production and the APSIM model for evaluation of soil conservation practices in the dryland of eastern Kenya. CMKEN, the Kenyan version of CERES-maize, was used to simulate maize yields comparable to those experimentally derived ( $R^2 = 0.88$ ). After validation, the APSIM model accurately predicted maize yield ( $R^2 = 0.94$ ) and was also tested for estimation of total soil N and C losses, through runoff at KARI-Katumani, under similar conditions.

**Key words:** APSIM, CERES-maize, CMKEN, KARI

### **Profitability and sustainability potential of growing maize using locally available soil fertility management options in western Kenya**

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The Research-Extension-Farmer linkages in most developing countries are considered to be weak due to lack of functional policies and inadequate budgetary support to strengthen the linkages. Due to this, it is no wonder that farming communities in developing countries continue to face many constraints in farming activities. The constraints range from lack of agricultural information, poor crop and animal husbandry methods, declining returns to capital invested in agricultural production, increasing food insecurity and increased environmental degradation

among others. In order to bridge the missing link, Folk Ecology Project was initiated in 2002 and given the mandate to develop and transfer soil fertility management options within the framework of Farmer Field School approach in western Kenya. Phase 1 (2002-2005) focused more on using organic residues in combination with inorganic fertilisers as the technical options. The organic resource data base developed by Tropical Soil Biology and Fertility Institute based in Nairobi shows that a variety of plant biomass leaf materials contain appreciable levels of nitrogen, phosphorus and potassium, which if augmented with mineral fertilisers could be a good source of plant nutrition, particularly for maize and horticultural crops. Fifteen different technical options were tried and maize was used as a test crop. The options included: -P-N (control), +P-N, +P+N, farm yard manure alone, farm yard manure +P-N, farm yard manure +P+N, *Tithonia diversifolia* alone, *Tithonia diversifolia* +P-N, *Tithonia* +P+N, *Calliandra calothyrsus* alone, *Calliandra calothyrsus* +P-N, *Calliandra calothyrsus* +P+N, Maize stover alone, Maize stover +P-N, Maize stover +P+N. The options were later disseminated by members of the Field School to the larger communities during practical weekly sessions and during field days. The results showed that the highest performing soil fertility option was the *Tithonia diversifolia* +P+N (average yield of maize 6.556 t ha<sup>-1</sup>); second was the *Tithonia* +P-N option (5.608 t ha<sup>-1</sup>), third was *Calliandra calothyrsus* +P+N option (4.667 t ha<sup>-1</sup>) and the least performing option was the control (-P-N) with an average yield of maize of 1.723 t ha<sup>-1</sup>. Marginal analysis on the data indicated that the most favourable shifts were: control to *Tithonia diversifolia* (495% MRR); control to *Tithonia diversifolia* (470% MRR) and control to *Tithonia diversifolia* only (315% MRR). The least favourable shifts was control to farm yard manure only (18.5% MRR). Other shifts from the control were favourable as well.

**Key words:** Nitrogen, phosphorus, small-holder farmers

### **Utilisation of phosphate fortified wheat straw compost for cereal production in Uasin Gishu District in Kenya**

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In Kenya, Uasin Gishu district is the leading wheat producer. Although, average annual yield of 1848 kg ha<sup>-1</sup> is attainable on-farm, wheat straw yields stand at 6 t ha<sup>-1</sup> crop yields and per capita food production have declined over the past two decades. The scenario of low crop yields, incomes and production are all traceable to soil nutrient mining by the farmers. Appropriate management practices of these crop residues have not been established. Burning is the most popular practice, yet this leads to loss of organic matter and nutrients. The fortification of these organic residues through composting is cheap and improves soil properties. This study focused on promoting the use of compost as a means of replenishing soil nutrients. The logit model analysis of the maximum likelihood estimates showed significant (p<0.05) socio-economic variables of age, time, labour, and technical know-how. Farmers should be encouraged to plant residues to make phosphate fortified compost.

**Key words:** Burning, organic residues, soil nutrients

### **Effect of soil fertility on Striga infestation in maize in western Kenya**

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Striga (*Striga hermonthica*) is a parasitic weed that attacks several cereals, but specifically maize and sorghum throughout Africa. In Kenya, Striga infestation is severe in the western and Nyanza provinces, where it occurs in about 200,000 hectares causing significant yield reductions in the two cereals. In recent years, Striga has spread into eastern Uganda and other African countries. Rather sizeable attempts have been made by researchers and farmers to manage Striga attack. These include: uprooting and burning the weed, use of tolerant cereal genotypes and use of herbicides. But most stakeholders believe that Striga is widespread in areas of low soil fertility. In a collaborative study testing the effectiveness of eight Striga management technologies, we tested surface soils (0-15 cm) from small-scale farms in Striga affected areas in Nyanza and western provinces in Kenya and eastern Uganda, to provide baseline soil fertility data prior to installment of technologies to reduce Striga. The soils data were to be used to examine relationship between Striga seed bank, maize yields and nutrient utilisation efficiencies under different management options. Apart from the generally low available phosphorus, the soils in the study area (240 farms) were moderately fertile, considering their total nitrogen levels in particular. There are differences in soil characteristics across districts and fields within farms. Striga seed counts varied significantly across and within fields of farms in Bondo district, had highest Striga seed population in an earlier study in 2004. However, there was no direct or simple relationship between Striga seed counts and soil fertility parameters at the beginning of the experiment. But the MBILI push Pull technology gave the highest maize grain yield (2.75 t ha<sup>-1</sup>), while the Striga susceptible H513 maize variety had the lowest yield (1.38 t ha<sup>-1</sup>).

**Key words:** MBILI, seed counts, soil fertility

### **Evaluation of local and exotic maize genotypes for tolerance to high soil acidity in Kenya**

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Acid soils are generally low in fertility and in such soils, the growth of maize is hindered mainly by aluminium toxicity and phosphorus deficiency. Increasing Al concentrations from 0 to 200 µM in nutrient growth medium had a differential negative effect on the seedling root growth depending on the genotype. Accessions 5A and 1x1 showed an increase in Final Root Length (FRL) when 200 µM Al was added. Al-tolerant standard from CIMMYT Cimcali 97 BSA 3-1) had a marked decrease of 63% which was comparable to the most sensitive accession 306B (66%). Accession 1x1 showed the highest Root Tolerance index (Rti) of 1.1 followed by 4D and 203B with an Rti of 1.0. Based on hematoxylin staining of roots, one accession (1x1) was classified as tolerant and sensitive standards respectively. Results of the field experiment showed that addition of phosphorus resulted into taller and vigorous plants. Landraces (5A, 2B4, 4C3, and

306B) were generally taller than the hybrids and the inbred lines. Addition of P increased the mean plant height by 8.8% while addition of P and lime increased the mean plant height by 6.2%. Application of lime alone did not seem to have an effect on plant height.

**Key words:** Aluminium, phosphorus, plant height

### **Soil fertility and crop yield changes in a continuous maize production in western Kenya**

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The per *capita* food production in Kenyan Highlands continues to decrease due to continuous cultivation with little or no external inputs leaving the soils highly deficient in nitrogen and phosphorus. Recently, the use of improved fallows and Minjingu phosphate rock (MPR) – a cheap source of P with long residual effects on soils has been promoted in western Kenya. However, the high rates recommended (250 kg P ha<sup>-1</sup> MPR) are prohibitive for small-scale farmers. The study was conducted in Busia district with the aim of evaluating changes in soil properties and maize yields over several seasons of continuous maize growth after application of low rates of MPR and fallow biomass. MPR was applied at 0, 20, 40 and 60 kg P ha<sup>-1</sup> in the first season, while the fallow biomass (*Crotalaria grahamiana* and *Tephrosia vogelii*) was incorporated after the harvest of the first season crop. No other fertiliser input was added in the subsequent seasons. Maize was planted in all the six seasons. At the end of each season, the soils were analysed for pH and Olsen P. Results showed slight pH increases in the first season of MPR application. However, in the subsequent seasons, significant differences in soil pH were observed following incorporation of fallow biomass. This was attributed to the release of organic acids from the decomposing fallows which resulted to increased Olsen P levels (6.85 mg P kg<sup>-1</sup>) in treatments with 60 kg P ha<sup>-1</sup>, MPR combined with crotalaria biomass (2 t ha<sup>-1</sup>). However, after the third season, Olsen P decreased significantly with time due to the high P sorbing capacity of these soils. Significant grain yield increases occurred in high rates of MPR application (60 kg P ha<sup>-1</sup>) in all the six seasons. The yields increased progressively up to the third season (2001 LR), which had yields ranging from 1.34 to 5.00 t ha<sup>-1</sup>. Thereafter, a continuous yield decline was noted whereby the lowest yield (0.34 to 1.35 t ha<sup>-1</sup>) was obtained in the sixth season (2002 SR). Therefore, at 60 kg P ha<sup>-1</sup> MPR, the residual benefits of MPR on Olsen P and crop yields may persist up to two seasons, thereafter, an addition of P fertiliser is necessary.

**Key words:** Kenyan highlands, Minjingu phosphate rock

## **PREP-PAC: A nutrient replenishment product for smallholders in western Kenya**

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Continuous cropping in the absence of external nutrient inputs to soil has led to the expression of poorly productive patches in farmers' fields of western Kenya. Farmers attempting to correct these conditions are often confused by the spatial and symptomatic irregularity of affected plants and, until recently no soil management product was commercially available that is specifically formulated to restore soil fertility to these patches. PREP-PAC consists of 2.0 kg of Minjingu rock phosphate (RP), 200 g urea, seeds of various symbiotic nitrogen-fixing food legumes, rhizobial inoculant, gum arabic seed adhesive, lime for seed pelleting and instructions for the use of these materials. It is intended for addition to 25 m<sup>2</sup> and produced at a cost of US\$ 0.56 per unit. The general principle is to apply slowly available RP sufficient for several cropping seasons with readily available nitrogenous fertiliser and to intercrop farmers' maize (*Zea mays*) with a legume that provides residual fixed-nitrogen and organic inputs to the soil. This approach was tested in on-farm experiments conducted in collaboration with several grassroots rural development organisations. An experiment examined interactions between PREP-PAC components in a maize-soybean (*Glycine max*) intercrop in nutrient-depleted soils with sandy and clayey surface horizons. The treatments included  $\pm$ RP,  $\pm$ urea and  $\pm$ inoculants. Total value of the intercrops ranged between US\$ 0.83 in the unamended plots and US\$ 2.44 in plots treated with PREP-PAC. Significant positive effects were observed with the addition of RP ( $p < 0.001$ ), urea ( $p = 0.04$ ) and inoculant ( $p = 0.01$ ) and in interactions between RP and urea ( $p = 0.02$ ) or inoculant ( $p = 0.07$ ). The return ratio of PREP-PAC investment was 2.6 in the sandy soil and 3.7 in the clay. PREP-PAC was tested on-farm in 52 symptomatic patches containing maize-bean intercrops with and without an improved variety of climbing *Phaseolus vulgaris* cv. Flora. Unamended patches (25 m<sup>2</sup>) produced 1.6 kg maize and 0.08 kg bean. With addition of PREP-PAC containing Flora, yields increased to 4.1 kg maize and 1.1 kg bean ( $p < 0.001$  for both crops). Improvement in bean yield during the first cropping season nearly offset PREP-PAC's investment costs. PREP-PAC is a strategic approach because all of its ingredients, except for urea, originate from East Africa, and are relatively inexpensive; the product is intended for distribution through existing retail and development networks.

**Key words:** Minjingu rock phosphate, rhizobia

## **Influence of lime on leaf yields of kales in acidic soils of Uasin Gishu in Kenya**

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Liming is a very essential practice for acid soils for improved plant yields. This research was carried out to determine the effect of various levels of lime on leaf yields of kales (*Brassica oleraceae var acephala*) in acidic soils of Uasin Gishu district, Kenya. The experiment was conducted in a greenhouse for 4-5 months. A surface soil described as Rhodic ferralsol, with

pH of 4.8, 2.1% C, 0.18% N and a texture of sandy clay loam (0-20 cm) was obtained from Kuinet area was used. Four levels of lime (0, 0.5, 1.0 and 1.5 tonnes per hectare) and blanket applications of 30 kg N urea ha<sup>-1</sup> and 40 kg P TSP ha<sup>-1</sup> was made. The yields of fresh kales leaves obtained from treatment 5 (L 1.5 t ha<sup>-1</sup> +30 kg N ha<sup>-1</sup> +40 kg P TSP ha<sup>-1</sup>) were the most superior in Kuinet area for kale production.

**Key words:** *Brassica oleraceae*, nitrogen, phosphorus

### **Effect of lime and phosphorus on soil chemistry and growth in soybean in acid soils of Uasin Gishu District in Kenya**

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Yields of legumes including soybean (*Glycine max*) have been declining over the recently situation that is worrying farmers in western Kenya. The decline is speculated to be caused by soil acidity i.e high exchangeable Al<sup>3+</sup> toxicity, and nutrient deficiencies. Soybean is an important ingredient for human food and animal feed. It is one of nature's most versatile plants and produces abundant supply of oil and protein both in temperate and tropical environments. The objectives of the study were to: (i) investigate the effect of lime and P additions on soil chemistry and early growth of soybean in acid soils, (ii) the effect of lime and P additions on the soil pH and P availability, and (iii) their effect on uptake of N, P and biomass production in soybean. The experiment was conducted in a green house in Chepkoilel, Uasin Gishu District, Rift valley Province, Kenya. The soils were acidic and deficient in essential nutrients resulting in low crop yields. TSP was used as a source of P and applied at 26 kg P ha<sup>-1</sup> was done at 2 t ha<sup>-1</sup>. Starter N (urea) was applied 2 weeks after planting at 15 kg N ha<sup>-1</sup>. pH and P availability were significant (p<0.05). This was also for the case of total dry matter. All the soil amendments increased soil available P, whereas soil pH was increased by the material containing CaO. There was a significant (p<0.05) correlation between total dry matter and shoot N and shoot P; and also between soil P and total dry matter.

**Key words:** *Glycine max*, nitrogen, phosphorus, rift valley

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### **Effect of single super phosphate on dissolution of Minjingu phosphate rock in a Kenyan soils**

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The effect of single super phosphate on the dissolution Minjingu phosphate rock was investigated in Tanzania, in different combinations of super phosphate and Minjingu phosphate rock were (a sparingly water soluble fertiliser). The percentage ratios of super phosphate to Minjingu phosphate rock of 10:90, 20:80, 30:70, 40:60, 50:50, 60:40, 70:30, 80:20, and 90:10 were studied in a laboratory incubation experiment. Three acid soils from the Rift Valley Province in Kenya were used. Treatments consisted of three P sources (super phosphate, Minjingu phosphate rock and mixtures of super phosphate and Minjingu phosphate alone), and three rates of applications (0, 200, and 800 mg P kg per dry soil). The samples were incubated for 30, 60 and 90 days. Solubility of Minjingu phosphate rock in the mixtures was enhanced in all the soils. Solubility increased with increasing proportion of super phosphate in the mixtures. Application of the fertilisers decreased the extractable Fe, and Mn in all the soils. Negative correlation coefficient though only significant for one soil, was obtained between extractable P and Fe, and P and Mn concentrations and these suggested that the dissolved Fe and Mn may precipitate P in solution and thereby reduce P availability.

**Key words:** Acid soil, Ca, Fe, Mn

### **Analysis of extreme rainfall and stream flow from the upper Ewaso-Ng'iro drainage basin in Kenya**

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Changes the upper Ewaso Ng'iro catchment in Kenya have greatly affected the trends of the stream flow and rainfall distribution patterns and series of hydraulic structure failures. There are inadequate design parameters in the basin which need good quality data. In light of the above, a study was conducted in three major categories as follows: data quality control, progressive trend analysis, design events derivation by frequency probability model. To verify the validity of the applied models, Intensity Duration Frequency curves estimations and comparison of observed and the derived values were carried out. The results of this comparison were found to be reasonable. Water control systems and management structures were designed based on hydrologic data measured or estimated. The measured data were used to calibrate frequency models for predicting design events. Rainfall and stream flow data were first extracted from ten gauging stations in the study site. Extreme Value Type I distribution fitting was confirmed by coefficient of determination and the relationship was perfect ( $R^2$  of 1.0). The Extreme Value Type I functions were derived and used to obtained design storms of 2, 5, 10, 50 and 100 years return periods. The deviations derived and observed storm values were in the range of 10.2 and 11.7%, which was within the reasonable limit. Log Pearson Type III fitness on stream flow data were verified by coefficient of determination which ranged from 0.94-0.97. Fitted log Pearson Type III distributions were used to simulate design stream flows for specified return periods.

**Key words:** Catchments, extreme value, Log person, type

## **Adoption of improved fallows and biomass transfer technologies in western Kenya**

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In the highlands of western Kenya, land productivity is very low due to continuous cropping with little or no soil fertility inputs. International Centre for Research in Agro-forestry (ICRAF) and partner organisations together with farmers developed low cost agro-forestry technologies to address low soil fertility. The purpose of this study was to assess the adoption and dissemination of biomass transfer and improved fallows technologies in Western Kenya. The study was carried out among 56 organisations disseminating the technologies in Western Kenya, and 99 farmers who were randomly chosen from ICRAF's test villages in Siaya and Vihiga Districts. The survey results from organisations indicated that female farmers were increasingly practising improved fallows and biomass transfer technologies. The most important benefits of improved fallows were: improvement of soil fertility, fire wood and stake production and weed control; while those of biomass transfer were: the increase in yields, cheap biomass and improvement of soil fertility. The limitations of improved fallows were land scarcity, pests and diseases and seed unavailability; while for biomass transfer they were unavailability of labour and biomass itself. Organisations and farmers also modified original agroforestry technologies to suit their needs. The weaknesses in assessing dissemination activities were that it involved time and physical resources for organisations involved, little follow up by ICRAF and no accurate records kept by some organisations. Result of the logit and multiple regression models showed that farm size (positive effect) and use of mineral fertiliser (negative effect) were the socio-economic factors significantly influencing the decisions to continue improved fallows. Improved fallows practice appeared to be gender neutral, and especially appropriate for low income farmers.

**Key words:** Agro-forestry, fertilisers, ICRAF, soil fertility

## **Surface soil management under varying rainfall intensity in river Njoro catchments in Kenya**

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The Mau Forest complex has experienced forest destruction to pave way for cultivation from as early as 1970s. The forest functions in the watershed have been affected with the formerly perennial rivers such as River Njoro, which drains the catchment into Lake Nakuru becoming seasonal. Due to increased erosion, the river deposits a lot of sediments into Lake Nakuru. This study assessed infiltration rates, surface runoff and soil erosion under selected land use practices as a basis for developing interventions. Field rainfall simulation at different rainfall intensities was used to examine infiltration, surface runoff and soil loss on natural forest, agricultural and grazing lands in this catchment. The study revealed significant difference in the mean runoff rate and soil lost from the three land use practices. Soil loss increased as rainfall intensity increased from 30 to 80 mm hr<sup>-1</sup> in the order of forest (0.0352 t ha<sup>-1</sup>, grazing (0.352 t ha<sup>-1</sup>) and agricultural land (1.45 t ha<sup>-1</sup>) which registered the highest loss. However, the highest mean runoff rate was recorded from grazing (26.46 mm hr<sup>-1</sup>) area, followed by agricultural

(21.01 mm hr<sup>-1</sup>) while forested land recorded the least runoff rate of 8.22 mm hr<sup>-1</sup> in all treatments. These results are useful in prioritising interventions for land and water management.

**Key words:** Infiltration, sedimentation, soil erosion, water retention

### **Adaptation of rainfall runoff models for runoff simulation in the humid zones of Kenya: A case study of the upper Ewaso Ngiro drainage basin**

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The design and operation of water resource management structures require reliable runoff data. Such data are available from catchments gauged with automatic recording instruments such as water level recorders and divers. However, in Kenya, such data are rare due to the high costs associated with the acquisition and maintenance of the instruments. This study explored the generation of runoff data through the use of conceptual rainfall-runoff models. Two lumped models, namely the Nash cascade-Diskin infiltration model and the Nash cascade-Green and Ampt infiltration models were used in this study. The models were applied in five catchments in the upper Ewaso Ngiro drainage basin in Kenya. Forty-five rainfall-runoff events were used to calibrate and validate the models. The conceptual parameters of the models on one hand were subjected to optimisation algorithms. The physical parameters of the models were obtained from the catchments characteristics with the help of Geographical Information System (GIS). The models satisfactorily simulated direct runoff in the five gauged catchments. In order to apply the models to un-gauged catchments of the same drainage basin, the models were regionalised by developing transfer functions relating the conceptual parameters of the models to the characteristics of the catchments. Transfer functions were then tested in the gauged catchments of the upper Ewaso Ngiro basin for use in un-gauged catchments. Results indicated that the two models had high potential for use in the direct runoff generation in un-gauged catchments.

**Key words:** Nash cascade, Nash cascade-Green and Ampt, runoff models

### **Bypass flow nitrogen losses in vertisols in a tropical environment**

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Bypass flow is one of the main avenues of fertiliser nitrogen loss in agricultural fields. The magnitude of fertiliser N carried in bypass flow is influenced by soil characteristics, nitrogen species (i.e., NH<sub>4</sub><sup>+</sup> or NO<sub>3</sub><sup>-</sup>) and rainfall patterns, *inter alia*. This study was designed to quantify the effects of fertiliser N source and rate, the onset of rains in relation to fertiliser application (i.e., wetting and no wetting before fertiliser application) on the fertiliser N recovered in bypass flow in a Vertisol. Also, the ammonium-N and nitrate-N adsorptive capacities of various Vertisols and non Vertisols were quantified. Three experiments were conducted. Experiment 1 comprised no wetting and pre-wetting of soil prior to fertiliser application, 2 rainfall intensities and 3 sources of fertiliser N. Experiment II involved 3 N sources, 3 N rates and 3 levels of rainfall frequencies. The bypass flow was collected, filtered and analysed for

mineral N. Treatments in Experiment III comprised 6 Vertisols and 2 non- Vertisols (i.e., Ferrasol and Nitisol). The soil charges (i.e.,  $\text{NH}_4^+$  and  $\text{NO}_3^-$  adsorptive capacities) were determined using the batch equilibration method. Wetting the soil prior to fertiliser application resulted in significantly ( $p < 0.05$ ) higher bypass flow and mineral N recovered in the effluent than did the non pre-wetting treatments. Both ammonium- and nitrate-N recovered in the bypass flow increased with rainfall intensity and frequency. Nitrogen source and rate resulted in significantly ( $p < 0.05$ ) different amounts of mineral N in the effluent. The effect of N source on ammonium-N in the effluent were in the order urea > ammonium sulphate > calcium nitrate, while the effect on N sources on nitrate-N were in the order nitrate > urea = ammonium sulphate. The increase in nitrate-N in the effluent due to fertiliser rate were in the order 200 > 100 > 50  $\text{Kg N ha}^{-1}$ . Ammonium-N losses were low being in the range 0.1 to 1%, while nitrate-N losses were high, being in the range 0.02 to 21% of the applied fertiliser. It is concluded that bypass flow is a major avenue of loss of nitrate-N in Vertisols.

**Key words:** Mineral nitrogen, adsorption, rainfall intensity

### **Effect of soil amendment with chickpea residue and inorganic nitrogen on soil hydraulic properties and wheat yield**

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Soil water retention and availability limit crop yields in many rain-fed areas in Kenya. Lack of a suitable fallow management strategy, mono-cropping and wheat-fallow rotations practiced in wheat growing areas deplete soil organic matter (SOM). Moreover, SOM is essential agent for aggregate stability and in turn water retention. Incorporating a drought tolerant legume such as chickpea in rotation with wheat offers a possible strategy to improve soil organic matter. This study examined the effect of incorporating chickpea residue into the soil under rotation with wheat on water retention and availability during the subsequent wheat crop. The main plot treatments were: chickpea ploughed into the soil at flowering stage, chickpea at maturity with the residue without seeds incorporated into the soil during land preparation for wheat, and fallow land, ploughed but not planted with the chickpea. The sub-plot treatments were inorganic fertiliser at three rates 0  $\text{kg N ha}^{-1}$ , 30  $\text{kg N ha}^{-1}$  and 60  $\text{kg N ha}^{-1}$ . Tension infiltrometers were used to measure steady state infiltration rates at two suctions, h -15 and -5 cm resulting in estimates of saturated hydraulic conductivity,  $K_{\text{sat}}$ . Disturbed soils sampled from the upper 15 cm soil layer were packed to a bulk density of 1.0  $\text{Mg m}^{-3}$  and pressure plate apparatus used to determine water retention at 0, -10, -33, -100, -300, -500, -1000, and -1500 kPa. Total soil organic matter was determined by loss of weight procedure, while size fractionation of particulate organic matter was done using the wet sieving method. Soil water retention was significantly influenced by the residue management techniques. The residue management techniques resulted in significant difference in the available water capacity. Incorporation of chickpea residues both as green manure and mature residues significantly increased the saturated hydraulic conductivity of the soil studied compared to the untreated soil. Residue management techniques and inorganic N rates did not significantly affect both above ground wheat biomass and grain yield. Particulate organic matter, labile and non-labile carbon fractions were not significantly affected by both residue management techniques and inorganic N rate. In drier conditions <500 kPa, mature chickpea improved water retention more than the green mature applied plots.

**Key words:** Fallow, legumes, mono-cropping, water retention

### **Effect of lime, phosphorus and rhizobium inoculation on bean growth and yield in an acid mollic andosol**

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Bean (*Phaseolus vulgaris* L.) yield in most small holder farms in Kenya is low due to low or no-use of fertilisers, poor soil management practices, inherent acid soil infertility, diseases and pests. A field trial was conducted to determine the potential for increasing bean yields in Molo, Kenya, on a mollic *Andosol*. Also, a greenhouse experiment was conducted at Egerton University in Kenya, to determine rhizobial populations at the trial sites. Three factors: lime, phosphorus and Rhizobium inoculation at 2, 3 and 2 levels, respectively were combined. Lime significantly ( $p < 0.05$ ) increased soil pH, available P, exchangeable Ca and Al, number and weight of nodules and grain yield in both seasons but was only significant on N and P plant contents and rhizobial populations in the second season. Phosphorus significantly ( $p < 0.05$ ) increased soil available P, number and weight of nodules, number of pods/plant and seeds/pod, grain yield, plant N and P contents in both seasons and rhizobial populations in the second season. Rhizobium inoculation significantly ( $p < 0.05$ ) increased plant N content and rhizobial populations in both seasons. There was a significant positive lime by phosphorus interaction on the number and weight of nodules in the first season and yield in the second season. Lime by rhizobium inoculation interaction significantly ( $p < 0.05$ ) increased weight of nodules and grain yield in the first season; and number of pods/plant and grain yield in the second season. Phosphorus by Rhizobium inoculation interaction significantly increased number and weight of nodules in the first season and yield in the second season. The lime by phosphorus by Rhizobium inoculation interaction only significantly increased number of nodules in the second season. Lime significantly ( $p < 0.05$ ) increased yields and reduced soil acidity stress hence liming is beneficial to bean production in acid soils. Phosphorus increased bean growth and yield. Higher yields were realised at  $120 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$  than  $60 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$  implying that high rates could be recommended for improved bean yields in acid soils. No yield response was observed with inoculation without P or lime in the mollic *Andosols*. Lime and phosphorus should be applied to enhance bean yields in mollic *Andosol*. In addition, the favourable response to inoculation though to a limited extent in some cases stresses the need for the adoption of these treatments either singly or in combination in acid soils.

**Key words:** Available P, liming, nodules, soil acidity

### **Land suitability classification for soybean in Kakamega district in Kenya**

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Introducing soybean (*Glycine max* L. merril), in a new area can only be successful when areas where it can grow has been delineated because climate and soils present a range of suitability levels for the crop. This study was conducted to delineate areas that present this suitability levels and to generate climate and land suitability maps for soybean cultivation in Kakamega district in Kenya Climatic characteristics (rainfall and temperature) for the same sites were obtained from the Almanac Characterisation Tool (ACT). Spatial maps on climate and soil data were prepared in a geographical information system (GIS), IDRISI32. Crop requirements and

their suitability ratings were used to evaluate soil and climate data in the Automated Land Evaluation System (ALES) through a qualitative matching process. Evaluation results were used to classify the spatial maps according to different climate and land suitability levels in IDRISI32 and the respective maps for both long and short rain seasons produced. Climate maps for the long rains season showed that 78% of the land is highly suitable while moderate and severe climatic limitations affect 21% and 1% of the land, respectively. For the short rains, 9% of the land is highly suitable while 90% and 1% have moderate and severe limitations, respectively. A combination of climate and soil information, excluding valleys, escarpments and forests that account for 18% of the total area, show that 80% of the land is suitable for growing soybean in Kakamega in both seasons. Land with very severe limitations (hence unsuitable) owing to soil reaction (pH), is 2%. The suitable land in the long rains exhibited 3% high suitability, 38% moderate suitability and 39% severe limitations; while in the short rains the distribution was 1, 40 and 39% respectively. The study revealed that there is more suitable land for growing soybean in the long rains than in the short rains.

**Key words:** ACT, ALES, CEC, GIS, soil texture

### **Effect of sediment deposition on the structure of benthic macro invertebrate assemblages in Lake Baringo, Kenya**

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The impact of sediment deposition on the benthic macro invertebrate abundance and taxa was studied in Lake Baringo in Kenya. Apart from high sediment load and fine sediment nature, depth plays a significant role on the total dissolved solids (TDS) and turbidity levels of Lake Baringo water. Shallow depth enhances complete mixing of the water column ensuing in the re-suspension of the already settled materials. This contributes to the lake's mean turbidity of  $689 \pm 245$  NTU and mean TDS of  $1003 \pm 376$  mg L<sup>-1</sup> of the period. A significant negative correlation between turbidity and TDS with benthic macro invertebrate abundance was observed (turbidity:  $r = -0.621$ , TDS:  $r = -0.609$ ,  $p = 0.01$ ). It was also observed that turbidity and TDS were highest at Kenya marine fisheries (KEMFRI) office site and lowest at Molo river mouth. A gentle decrease in turbidity and total dissolved solids was observed at Molo river mouth during the study. Similarly high benthic macro invertebrate abundance and taxa diversity were recorded at Molo river mouth, while the lowest was at KEMFRI office site. Molo river mouth had the highest number of taxa. High percentage clay level was recorded at Molo river mouth, while high percentage of silt and loam were observed at Kambi ya Samaki and KEMFRI office site, respectively. The high clay and silt content at these sites have resulted in decreased interstitial space in the sub-stratum before changing benthos structure to predominantly burrowing oligochaetes and chironomids. Despite these spatial and temporal differences, there were no significant differences in benthic macro invertebrate's sizes among the sampling sites and occasions.

**Key words:** Clay, dissolved solids, silt, taxa, turbidity

### **Effectiveness of phosphate rock in an acid soil as affected by source, particulate size and reaction time**

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The effectiveness of two reactive phosphate rock (RP) relative to a superphosphate fertiliser, and the effect of particle size and timing of application of a reactive PR fertiliser were studied in Kenya under incubation and glasshouse experiments using an acid soil with high P adsorption capacity. In the first experiment, a Tanzanian PR fertiliser (Minjingu PR), a Tunisian PR (Gafsa PR) and single superphosphate were added to the soil at rates of 0, 50 and 100 mg P kg<sup>-1</sup> soil and incubated for six weeks. The extent of dissolution and NaHCO<sub>3</sub>-extractable P levels was measured and a pot experiment was subsequently carried out using maize (*Zea mays* L.) as an indicator crop. Results showed that the difference in yield and P uptake between superphosphate-treated samples and PR-treated samples were small, although large differences in NaHCO<sub>3</sub>-extractable P levels between superphosphate-treated samples and PR-treated samples were observed before the start of the pot experiment. In the second experiment, Gafsa PR was ground to three particle size ranges: 20-mesh (<750 µm), 40-mesh (<370 µm) and 100-mesh (<150 µm) and added to the soil at the above rates of application. The samples were incubated for either one or six weeks, and extents of dissolution as measured by NaHCO<sub>3</sub>-extractable P levels determined before carrying out a pot trial. NaHCO<sub>3</sub>-extractable P levels (dissolution), yield and uptake decreased with increasing period of fertiliser reaction with the soil. The results indicated that the differences between particle size effects may become less significant if the fertilisers are reacted with the soil for a long time.

**Key words:** Dissolution, fixation, P-adsorption, P-uptake

### **Soil seal formation and crop yield under semi arid conditions**

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Soil erosion and runoff are serious and wide spread land degradation problems in many parts of the world, especially in arid and semi-arid regions in Africa. This study was conducted to investigate the effect of soil mineralogy, texture and slope gradient on seal formation and its properties and their effects on infiltration, run off and soil erosion. Water and soil conservation effect on infiltration, erosion and crop yield under seal formation conditions in semi-arid conditions was also investigated. Soils with different mineralogy and texture were subjected to 80 mm of simulated rainfall at 9% slope gradient. Mean weight diameter (MWD) values were 2.8 mm in the kaolinitic soil, 0.25 and 0.31 mm in the montmorillonitic soils, and 0.84 and 0.87 mm in the non-phyllosilicates soils. The final infiltration rate (IR) was 20.5 mm h<sup>-1</sup> in the kaolinitic soil and 9.3 mm h<sup>-1</sup> in the montmorillonitic soils. The kaolinitic soil had a thin crust (~0.1 mm) containing large particles (~0.1 mm), while the montmorillonitic soils had thicker crusts (<0.2 mm) comprising either small (~0.02 mm) ones with a very developed "washed in" zone underneath, or large (~0.2 mm) ones with fine material between them. Crust layer in the non-phyllosilicates soils was ~0.2 mm and composed of fine particles ~0.01 mm. The high aggregate stability and the low dispersivity of the kaolinitic soil, which decreased the soil detachment; and its low runoff, which decreased the transport capacity, limited the soil loss to 0.33 kg m<sup>-2</sup>. The low aggregate stability and high runoff of the montmorillonitic soils contributed to their

soil losses of 1.24 and 1.14 kg m<sup>-2</sup>. The intermediate aggregate stability and the high runoff of the non-phyllsilicate soils accounted for their intermediate soil losses of 0.75 and 0.8 kg m<sup>-2</sup>. In another study, kaolinitic and montmorillonitic soils were subjected to 80 mm of simulated rainfall at 9, 15, 20, and 25% slope gradient. The slope factor (Sf) values of the kaolinitic soil at slope gradient >9% were lower than the corresponding values of the montmorillonitic soils. A positive linear regression significantly fitted the relation between the relative MWD (the ratio of the MWD values at any slope gradient to that at 9% slope) values and the corresponding Sf values at 99% confidence level ( $r^2=0.78$ ). The indigenous soil and water conservation techniques (ISWC) techniques significantly decreased the run off and the soil loss, and increased the maize and cowpea yields. The BTL was the most effective technique, but no consistent differences were found between the STL and SL techniques. In BTL, STL, SL and the control, seasonal average runoff for each treatment was 25, 31, 29 and 51 mm, respectively, and the seasonal average soil loss was 0.23, 0.33, 0.3 and 0.67 t ha<sup>-1</sup>, respectively.

**Key words:** Kaolinitic, mineralogy, moisture, montmorillonitic, slope

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