Integrated Soil Fertility Management in Africa: from Microbes to Markets (ISFM Africa 2012)

Conference Information, Program and Abstracts

A short history of ISFM in Africa is captured in this series of quotes ...

The soil nutrient losses in sub-Saharan Africa are an environmental, social, and political time bomb. Unless we wake up soon and reverse these disastrous trends, the future viability of African food systems will indeed be imperiled. Norman Borlaug, 2003

The African Union Member States resolve to increase the level of use of fertilizer from the current average of 8 kilograms per hectare to an average of at least 50 kilograms per hectare by 2015. African Fertilizer Summit, 2006

ISFM is the application of soil fertility management practices, and the knowledge to adapt these to local conditions, which maximize fertilizer and organic resource use efficiency and crop productivity. Bernard Vanlauwe, 2009

An overall nutrient supply strategy "N from the air and others from the bag" offers flexible adjustment to local conditions and opportunity for optimizing the use of available agro-minerals. ... ISFM empowers farming households to wiser decisions concerning crop enterprise and resource management on a daily basis. Nteranya Sanginga and Paul L. Woomer, 2009

But how far have we really come to assure that small-scale farmers have the knowledge, technologies and products to engage with ISFM and what must we do to move forward more effectively in the future? ISFM Africa 2012 Organizers

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Citation: Woomer, P.L. (Editor). 2012. Integrated Soil Fertility Management in Africa: from Microbes to Markets: Conference Information, Program and Abstracts. An international conference held in Nairobi, Kenya, 22-26 October 2012. CIAT. 122 pp.

Cover design by Paul L. Woomer. Line drawings by Nicholas Mwema.

Welcome and Purpose of ISFM Africa 2012

Welcome to the ISFM Africa 2012 Conference and thank you for your participation. This conference results from the combined efforts of allied organizations and projects accelerating delivery of needed agricultural technologies to African small-scale farmers. They have combined several recurrent events relating to the management of soils and beneficial organisms including the 15th Conference of the African Association for Biological Nitrogen Fixation (AABNF), the 2nd Workshop of the African Network on Mycorrhiza (AFRINOM) and the Biannual Conference of the African Network for Soil Biology and Fertility (AfNet). But this is more than just an aggregation of meetings. It is intended to critically analyze agricultural technologies, innovative microbial based products and land management strategies benefiting small-scale agriculture in Africa. It assembles the strengths of several organizations and collaborative research projects committed to designing, refining and delivering potent solutions to food insecurity and agricultural resource degradation in sub-Saharan Africa. A particular focus of this conference deals with the comparison and scaling-up of candidate breakthrough technologies, monitoring and evaluation of their impacts within rural settings and along agricultural value chains. The conference is structured along six Themes:

Theme 1: ***Advancing plant-microbe interactions in crop nutrition.*** This theme includes symbiotic and plant growth promoting microorganisms relating to crop mineral nutrition, but not those relating to plant protection and health.

Theme 2: ***Enhancing biological nitrogen fixation in African smallholds.*** This theme explores the use of elite rhizobia, improved legume varieties and management and effective inoculant delivery systems. The sessions relating to this theme constitute the 15th Conference of the African Association of Biological Nitrogen Fixation.

Theme 3: ***Exploring options for intensification and diversification of farming systems.*** This theme examines the more efficient use of human and agricultural resources in the restoration, protection, maintenance and improvement of soil fertility with particular reference to technologies and practices accessible to small-scale farmers cultivating degrading soils.

Theme 4: ***Identifying bottlenecks and opportunities for implementation of ISFM***. This theme addresses issues pertaining to governance, policy formulation and implementation, tenure, access to markets and credit and perceptions and countermeasures toward risk.

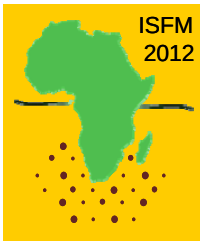
Theme 5: ***Commercializing breakthrough technologies.*** This theme explores how proven scientific findings are best translated into commercial products and practical land management technologies for dissemination to, and adoption by African smallholders. This theme also examines mechanisms of quality assurance related to these new products and lessons learned through entrepreneurial pursuit.

Theme 6: ***Building capacity in Integrated Soil Fertility Management.*** This theme explores how best to develop capacities among farmers, development agents, researchers and educators in Africa to better manage soil fertility and agricultural resources. Preference is given to case studies describing success stories at the farm, community and institutional levels.

Ultimately, the conference is intended to increase human and institutional capacities in Integrated Soil Fertility Management (ISFM) and identify and advance candidate, breakthrough and proven agricultural technologies that may benefit Africa's poorest farmers. These technologies include better management of Biological Nitrogen Fixation and other beneficial biological processes; strategic combination of biological, organic and mineral resources in the management of soil fertility and land quality and the commercialization and adoption of new biotechnologies. The conference highlights ISFM as a rural development paradigm in rural development and a productive, sustainable livelihood strategy for small-scale farmers. Finally, the conference offers opportunity for collegial discussion among academics, students and stakeholders in soil and land management, to celebrate our success and stiffen our resolve to better conserve Africa's agricultural resources, bring prosperity to its rural communities and achieve food and nutritional security to the continent.

The Conference Organizers,
22 October 2012

Sponsors of the ISFM Africa 2012 Conference



The African Association of Biological Nitrogen Fixation (AABNF)

The African Network on Mycorrhiza (AFRINOM)

Africa Soil Health Consortium (CABI)

The International Center for Tropical Agriculture

Commercial Products Project II (B&MGF)

Food and Agriculture Organization of the United Nations

Research Institute of Organic Agriculture (FiBL)

The International Institute of Tropical Agriculture (IITA)

MEA Fertilizers Limited (Kenya)

Kenya National Council for Science and Technology

Putting Nitrogen Fixation to Work for Smallholder Farmers in Africa (N2Africa Program)

Swedish University of Agricultural Sciences

United States International University: Kenya

University of Nairobi Microbial Resource Center (MIRCEN)

The organizers of ISFM Africa 2012 greatly appreciate the assistance and financial support provided the above-listed sponsors, organizations that literally assist in the development of ISFM in Africa from microbes to markets

Venue, Advisory Board, Local Organizers and Conference Secretariat

Venue

Integrated Soil Fertility Management in Africa: from Microbes to Markets (ISFM Africa 2012) convenes at the Safari Park Hotel, Nairobi, Kenya from 22 to 26 October 2012. For more information, visit the conference website at *www.isfmafrica2012.org*.

International Organization Committee

Dr J.J Adu-Gyamfi (International Atomic Energy Agency)
Prof Amadou Bâ (IRD Senegal and President of AFRINOM)
Dr André Bationo (AGRA)
Prof Felix Dakora (Tshwane University of Technology, South Africa)
Dr. Yoland Dalpé (ECORC, Agriculture and Agro-food Canada)
Dr Joanna Dames (Rhodes University and AFRINOM)
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Dr Rachid Serraj (ICARDA)
Prof Bernard Vanlauwe (IITA)
Dr Prem Warrior (Bill & Melinda Gates Foundation)
Dr Christian Witt (Bill & Melinda Gates Foundation)
Prof Inamoud Yattara (African Association for Biological Nitrogen Fixation)

Local Organization Committee

Dr. Kenton Dashiell: IITA : Co-Chairperson, IITA
Dr. Joyce Jefwa: CIAT (Coordinator of the 2nd AFRINOM Workshop)
Dr. Saidou Koala: CIAT: Co-Chairperson, CIAT-Kenya
Prof. James Kahindi: US International University (USiU)
Prof. Nancy Karanja: University of Nairobi (Coordinator of AABNF 15 Sessions)
Dr. Peter Okoth: CIAT-Kenya
Dr Kristina Roing de Nowina: IITA and Swedish University of Agricultural Sciences
Dr Cécile Thonar: COMPRO and FiBL
Dr. Paul L. Woomer: N2Africa Program and AABNF

Information on oral presentations

1. Session speakers are provided 20 minutes and should prepare for a 15-17 minute presentation with 3 to 5 minutes for short questions and answers. Speakers must strictly remain within these time limits as Session Chairpersons will reinforce these time limits and abruptly terminate any presentation that goes overtime.
2. Presentation preview facilities are located in the Lioness Room, next to the Conference Secretariat upstairs from the main conference room. Presentations must be prepared in MS Windows Powerpoint as .ppt or .pptx files. Those unable to meet this requirement must contact the Secretariat well in advance of their presentation so that other arrangements can be made. All speakers are encouraged to preview their presentations but must meet with the Session Coordinator in the Lioness Room at the indicated times to upload their presentations.
3. The Session Coordinator is responsible for collecting presentations from the speakers and loading them into the Session computers. Session Coordinators will be available in the Lioness Room prior to the Morning Session (for Keynote Speakers) and during the 40 minute health break and 60 minute lunches immediately before each session (for Session speakers). Five minutes before the scheduled sessions, the Session Coordinator will leave the Preview Room to load presentations onto Session computers. To avoid unnecessary delay, we ask that all speakers take advantage of this facility. Speakers that fail to load their presentations in advance, or that insist on using their own computers will have wasted time deducted from their presentations by the Session Chairperson.
4. The schedule for uploading presentations in the Lioness Room follows:

Monday, 22 October		
Morning Plenary	Opening Addresses	0830-0850
	Theme 1 and 2 Keynote Addresses	1010-1030
Afternoon Sessions	Sessions A, B and C	1330-1350
Tuesday, 23 October		
Morning Plenary	Theme 3 and 4 Keynote Addresses	0830-0850
Morning Sessions	Sessions A, B1, B2 and C	1030-1050
Afternoon Sessions	Sessions A1, A2, B1, B2 and C	1330-1350
Thursday, 25 October		
Morning Plenary	Theme 5 and 6 Keynote Addresses	0830-0850
Morning Sessions	Sessions A, B and C	1050-1110
Afternoon Sessions	Sessions A, B and C	1330-1350
Friday, 26 October		
Morning Sessions	To be arranged by Business Meeting organizers	
Afternoon Plenary	To be arranged by FAO Policy Forum organizers	

Information to poster presenters

1. The poster exhibition will take place in the lobby of the Jambo Conference Room. All posters will be displayed throughout the conference but special times are also designated for poster presentation by authors. Poster Sessions also coincide with morning and afternoon health breaks and poster displays and service areas are adjacent. Please take time appreciate these posters and attend the author's presentation of those you find of greatest interest.
2. Poster boards space is allocated by reference numbers appearing in this booklet. Posters relating to the same and similar sessions appear together. Please take effort to assure that posters are hung in the allocated space. Posters should be hung between 0800 and 0850 on Monday morning, and at latest 0950 Monday just before the first designated poster session. Authors should remove their posters following the final poster session at 1620 on Friday. Any posters not recovered by authors before 1830 on Friday will be removed by the conference staff and discarded without notice.
3. Poster presenters are expected to attend their posters at designated times. All poster presenters are expected to attend their posters between 1220 and 1300 on Monday, 22 October. In addition, authors are expected to attend their posters at certain designated times as follows:

Monday 22 October
1000 - 1040 All posters available for viewing, authors attend posters A1 to A22 and B1 to B14
1220 - 1300 All authors attend their posters for questions and discussion
1520- 1540 All posters available for viewing, authors attend posters C1 to C14

Tuesday, 23 October
1020 - 1100 All posters available for viewing, authors attend posters C15 to C43
1520 - 1540 All posters available for viewing, authors attend posters C44 to C60

Thursday, 25 October
1040 - 1120 All posters available for viewing, authors attend posters C61 to C85
1520 - 1540 All posters available for viewing, authors attend posters C86 to C102

Friday, 26 October
1040 - 1120 All posters available for viewing, authors attend posters D1 to D20
1540 - 1620 All posters available for viewing, authors attend posters D21 to D28 and E1 to E5

Internet Access

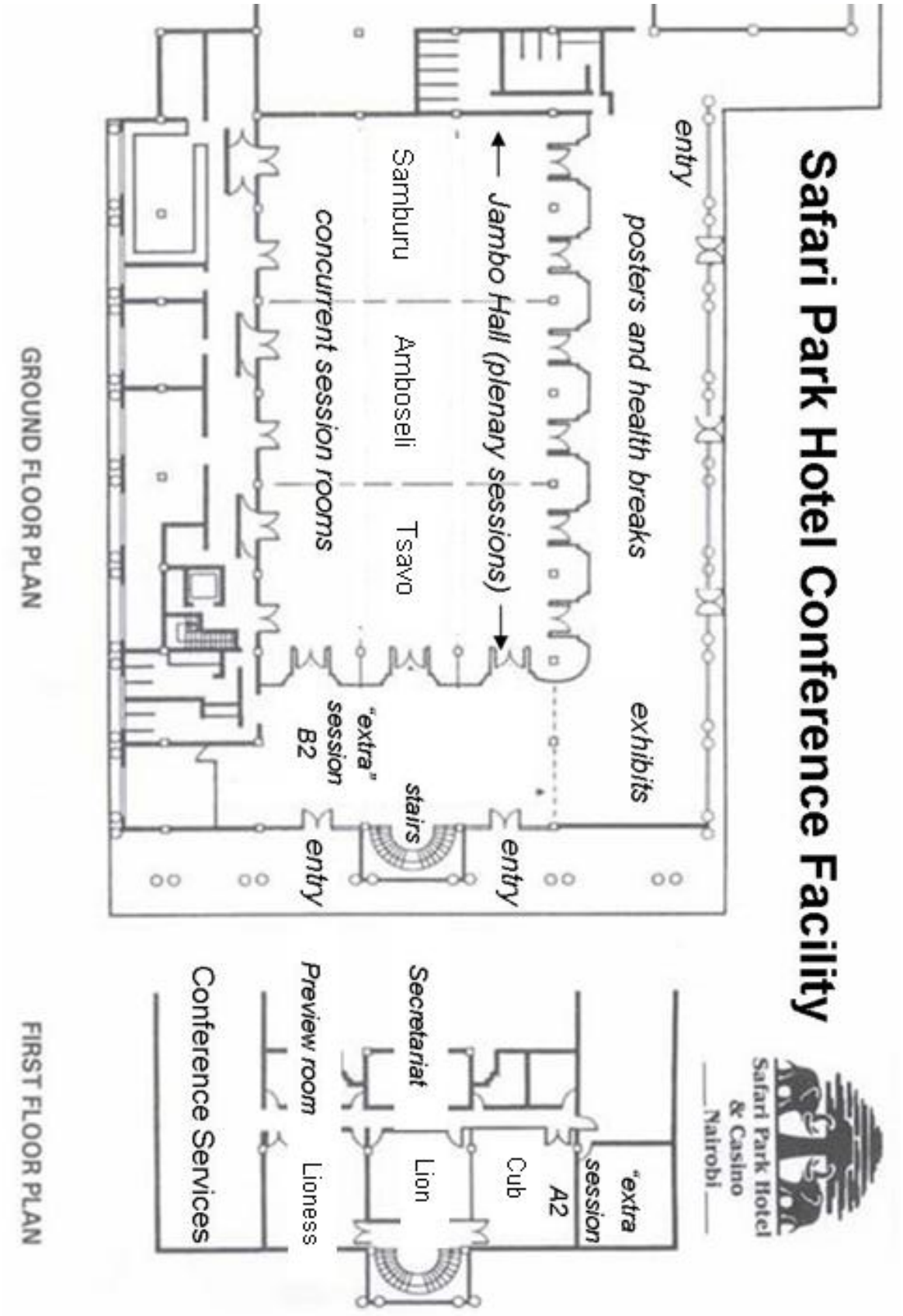
Conference participation includes wireless internet access but this access is available in and around the Conference Rooms only. A blanket code will be distributed to conference participants to key in their web browsers at registration and during the opening of the meeting. Internet can also be accessed by guests of Safari Park Hotel in two ways, either cable or wireless. Cabled internet is available only in the hotel rooms whereas wireless is accessible both in the conference rooms and the guests rooms. The management of Safari Park Hotel advises that all guests connect via their rooms in advance before the meeting to avoid inconvenience in the conference rooms, where a large number of participants will likely attempt to access the internet at the beginning of the meeting. ICT support by Safari Park Hotel is coordinated by Steve Oliech (mobile phone number 254-726-319501) who may also be contacted through the Secretariat.

Conference Services

The Conference Secretariat is located in the Lion Room upstairs of the main Jambo Hall and will operate from 0830 to 1730 hours during the conference except for Wednesday, 24 October (the day of field excursions). Services offered by the Secretariat include flight reconfirmations and changes; late registration; late booking for conference excursions and late payment for the conference dinner on Thursday, 25 October; arrangements for taxi service and assisting transport for participants staying away from the main conference venue; assisting participants to arrange internet access; and processing reimbursement requests for sponsored participants. Participants are encouraged to make use of these services. Next to the Lion Room, participants will find the Lioness Room where preview facilities for oral presentations are provided. Speakers *should not submit their presentations to the Secretariat* in the Lion Room, rather they are expected to provide their presentations to the Session Coordinator in the Lioness Room next door according to the schedule above. Secretariat members and their respective responsibilities include:

Secretariat supervision: *Jacqueline Odongo*
Late registration: *Linda Wangila* (Registrar) and *Caleb Mulogoli* (Cashier)
Registration for field excursions: *Mildred Okoth* (Registrar) and *Caleb Mulogoli* (Cashier)
Presentation preview room: *Mita Sambo*
Transferring presentations to sessions: *Ivan Adolwa*
Local transportation and accommodation: *Mildred Okoth*
Assisting poster presenters: *Isaac Savini*
Internet connectivity: *Steve Oliech*

Conference Facilities and Meeting Rooms



Conference Program

Integrated Soil Fertility Management in Africa: From Microbes to Market

Safari Park Hotel, 22 to 26 October 2012, Nairobi, Kenya

Sunday, 21 October

1500 - 1800 Registration of participants. Safari Park Hotel Lobby

Monday, 22 October

Morning Session Plenary and Posters

0800 - 0900 Registration of participants (continued). Jambo Conference Hall Lobby
0900 - 0920 Opening Ceremony. Jambo Conference Hall. Chairperson: *Dr. Kenton Dashiell*
0920 - 1000 Opening Address: Setting the scientific scene for ISFM in Africa: Inception, status, future, and more. *Dr. Bernard Vanlauwe*

1000 - 1040 Health break and Poster Session. Poster presentations A1 to A22 and B1 to B14

1040 - 1120 Theme 1 Keynote Address: Mycorrhizal agro-technology for Africa: Challenges and future prospects. *Dr Joanna Dames*
1120 - 1200 Theme 2 Keynote Address: Symbiotic rhizobia are key to enhanced soil fertility, increased crop yields and improved human nutrition. *Felix D. Dakora*
1200 - 1220 Plenary discussion of Opening Address and Themes 1 and 2 (short statements and questions)

1220 - 1300 Poster Session in Jambo Lobby. All authors attend their posters

1300 - 1400 Lunch

Afternoon Concurrent Sessions A, B and C

Concurrent Session A. Theme 1: Advancing plant-microbe interactions in crop nutrition; Integration of mycorrhiza into agroecosystems

1400 - 1420 Convening AFRINOM and organizer's announcements. Chairperson: *Dr. Joanna Dames*
1420 - 1440 Use of arbuscular mycorrhizal fungi as bioenhancers: are we ready? *Dupré de Boulois Hervé*.
1440 - 1500 Use of arbuscular mycorrhiza and different sources of phosphorus: applications to the domestication of the jujube tree. *Bâ Amadou*
1500 - 1520 Effects of arbuscular mycorrhizal fungi on growth, water relation and antioxidant enzymes activities in Moroccan picholine olive plantlets under water stress. *Qaddoury Ahamed*

1520- 1540 Health Break in Jambo Lobby and poster viewing. Poster presentations C1 to C14

1540 - 1600 Effect of arbuscular mycorrhiza and plant growth promoting rhizobacteria on wheat–rice and wheat–vigna cropping systems. *Srivastava Rashmi*
1600 - 1620 Growth and yield response of *Corchorus olitorius* to treatments of arbuscular mycorrhizae, poultry manure and inorganic fertilizer. *Cyril Nwangburuka*
1620 - 1640 Evaluation of varying time of application of myccorrhiza inoculum on vigour of growth and root development of cacao seedlings in the nursery. *Famuwagun Iduwu Babadele*
1640 - 1700 Discussion on application of mycorrhiza

Concurrent Session B. Theme 2: Enhancing biological nitrogen fixation in African farming systems; Recent Advances in BNF

1400 - 1420 Convening AABNF 15 and organizer's announcements. Chairperson: *Prof. Nancy K. Karanja*
1420 - 1440 The curse of nitrogen deficiency in Africa: Can pigeon pea play saviour? *Kizito Kwena*
1440 - 1500 Enhancing biological nitrogen fixation in smallholder farms through rhizobial inoculation in the Nigerian Guinea Savanna. *Abdullahi Bala*
1500 - 1520 Response of *Acacia senega*l provenances to inoculation with selected rhizobial strains in relation to soil origin. *Niokhor Bakhoum*

1520 - 1540 Health Break and poster viewing in Jambo Lobby. Poster presentations C1 to C14

1540 - 1600 *B*-value and isotopic fractionation during N_2 fixation by faba beans. *Amsalu Nebiyu Woldekirstos*
1600 - 1620 Bio-prospecting elite soybean and bean rhizobia in Kenya. *Nancy Karanja (for George Mwenda)*
1620 - 1700 Discussion on Recent Advances in BNF

Concurrent Session C. Theme 6: Building capacity in Integrated Soil Fertility Management

1400 - 1420 Introduction to Theme 6. Chairperson: *Dr. Monicah Mucheru-Muna*
1420 - 1440 Fostering South-South knowledge sharing for ISFM capacity building in agricultural landscapes in Southern Africa. *Edmundo Barrios*
1440 - 1500 How farmer field schools and farmer-to-farmer videos empower farmers differently: the case of integrated striga and soil fertility management in West Africa. *Tom Van Mourik*
1500 - 1520 Building future ISFM managers: incorporating school centered approach with farmer field schools. *Mary Nyasimi*

1520 - 1540 Health break and poster viewing in Jambo Lobby. Poster presentations C1 to C14

1540 - 1600 Enhancing the responsiveness of smallholder communities to persistent problems of food insecurity and pending challenges of increased climate variability. *Florence Mtambanengwe*
1600 - 1620 Cropping systems and existing technologies of soil fertility management should be considered to improve crop production in West Africa*. Delwendé I. Kiba*
1620 - 1640 Going through paces; empowering communities to use improved crop production practices to adapt to climate change and variability through field-based learning centres in Zimbabwe. *Regis Chikowo*
1640 - 1700 Discussion on building capacity in ISFM

Tuesday, 23 October

Morning Plenary Session and poster viewing

0850 - 0900 Conference announcements and plenary opening. Chairperson: *Dr. Saidou Koala*
0900 - 0940 Theme 3 Keynote Address: Exploring options for sustainable intensification and diversification of farming systems through integration of grain legumes. *Prof. Ken Giller*
0940 - 1020 Theme 4 Keynote Address: ISFM in Africa: getting the policies right. *Dr Ademola Braimoh*

1020 - 1100 Health break and Poster Session Themes 3 and 4 in Jambo Lobby. Poster presentations C15 to C43

Morning Concurrent Sessions A, B and C

Morning Concurrent Session A. Optimization of mycorrhizal interventions and adaptation
Chairperson: *Dr. Bâ Amadou*

1100 - 1120 Biochar effects on arbuscular mycorrhizal fungi. *Edith Hammer*
1120 - 1140 Impacts of phosphorus type and spatial relation to biochar on bean-mycorrhizal symbioses and crop phosphorus nutrition in a degraded acrisol. *Steven Vanek*
1140 - 1200 Effects of tillage and cropping systems on arbuscular mycorrhizal communities in Western Kenya. *Mary Muriithi Muchane*
1200 - 1220 La fertilisation du sol avec des poudres d'algues est améliorée par l'inoculation endomycorhizienne : cas du développement de plante de tomate. *Dina Ratahiriarisoa*
1220 - 1240 Integration of commercial products into soil fertility practices as potential options for acclimatilization of tissue culture banana. *Agnes Kavoo*
1240 - 1300 Discussion on mycorrhizal interventions

Morning Concurrent Session B1. BNF in Smallholder Production Systems
Chairperson: *Paul L. Woomer*

1100 - 1120 Do we really need to inoculate cowpea and green gram with commercial inoculants to improve yield and nitrogen fixation? *Samuel Mathu*
1120 - 1140 Symbiotic nitrogen fixation and soil nitrogen balance as influenced by groundnut genotypes in Nigeria. *Ado Yusuf*
1140 - 1200 Biological nitrogen fixation of soybean inoculated with *Bradyrhizobium japonicum* in Benin. *Zoundji Charlotte*
1200 - 1220 Effects of phosphorus and micronutrients on inoculation response by soybean. *Faruk Umar*
1220 - 1300 Discussion on BNF in smallholder production systems

Morning Concurrent Session B2. Breakthroughs in inoculation
Chairperson: *Dr. Maria Luisa Izaguirre-Mayoral*

1100 - 1120 Effect of bradyrhizobium inoculation and phosphorus application on soybean in Benin. *Pascal Houngnandan*
1120 - 1140 Effect of cattle manure, mineral fertilizer and rhizobium inoculation on climbing beans and soil properties in Rwanda. *Musaninkindi Nadia*
1140 - 1200 The effect of the inoculation on the growth and yield of *Vigna unguiculata* under salt stress. *Nour Elhouda Abed*
1200 - 1220 Rhizobium strains increase nitrogen fixation in Kivu, DR Congo. *Espoir Bagula*
1220 - 1240 Sustainable intensification of farming systems through legume technologies: Lessons learnt for expansion of N2Africa to new countries. *Esther Ronner*
1240 - 1300 Discussion on breakthroughs in inoculation

Morning Concurrent Session C. Theme 3: Exploring options for sustainable intensification and diversification of farming systems

1100 - 1120 Introduction to Theme 3. Chairperson: *Prof. Ken Giller*
1120 - 1140 Calibration and validation of AquaCrop model for maize in sub-humid and semi-arid regions of Central Highlands of Kenya. *Daniel Mugendi*
1140 - 1200 Experiences on the up-scaling of seed priming and micro-dosing in millet and sorghum areas in Mali. *Jens Aune*
1200 - 1220 Improving maize productivity: the option of rice husk biochar in Ghana. *Edward Yeboah*
1220 - 1300 Discussion on exploring options intensification and diversification

1300 - 1400 Lunch

Afternoon Concurrent Sessions A, B and C

Afternoon Concurrent Session A1: Mycorrhiza in ecosystems management
Chairperson: *Dr. Quddoury Ahamed*

1400 - 1420 Soil microbial diversity and alien plant invasion: insights through a multi-scale approach *Khasa Damase*.
1420 - 1440 Arbuscular mycorrhizal fungal communities differ between co-occurring indigenous tree species: its implication in the reforestation of East African Afromontane forests. *Tesfaye Wubet*
1440 – 1500 Reactivation of fungal propagules in disturbed and degraded soils by pioneer plant species: improving soil chemical and microbial quality. *Baohanta Rondro Harinisainana*
1500 - 1520 Mycorrhiza alters competitive interactions of *Acacia* and *Boswellia* seedlings in drought pulsing. *Birhane Hizikias Emiru*

1520 - 1540 Health Break and poster viewing. Poster presentations C44 to C60

1540 - 1600 Mycorrhizal fungi of Malian soils. *Ousmane Sacko*
1600 - 1620 Diversity of arbuscular mycorrhizal fungi associated to potato crop under gradient of nutrients stress in Morocco. *Hamim Ahlam*
1620 - 1640 Diversité des champignons mycorhiziens arbusculaires associés au niébé en fonction de la typologie des sols au Sénégal *Diop Ibou*
1640 - 1700 Discussion on maximizing benefits of mycorrhiza

Afternoon Concurrent Session A2. Alternative Interventions
Chairperson: *Edith Hammer*

1400 - 1420 Shared ectomycorrhizal symbionts between *Uapaca bojeri* and *Sarcolaena oblongifolia* facilitate the establishment of native tree seedlings in degraded sclerophyllous forest of the Madagascarian highlands. *Ramanankierana Heriniaina*
1420 - 1440 Potential influence of organic acids from ectomycorrhizal fungi on weathering of iron ore minerals. *Adekele Rasheed*
1440 - 1500 Diversity and specificity of fungal communities associated with epiphytic species of *Angraecum bory* (*Orchidaceae*) in Atlantic Central Africa. *Diédhiou Abdala Gamby*
1500 - 1520 Selection of phosphate-solubolising plant growth promoting microorganisms for use in Cameroon. *Henri Fankem*

1520 - 1540 Health break and poster viewing. Poster presentations C44 to C60

1540 – 1600 Effets interactifs d'une bactérie solubilisant le phosphate naturel de Tilemsi et des champignons. *Babana Amadou Hamadoun*
1600 - 1620 Indigenous arbuscular mycorrhizal fungi (AMF) improve field establishment of tissue cultured AAA-EA and AAB bananas in Rwanda. *Rurangwa Edouard*
1620 - 1700 Discussion on maximizing benefits of mycorrhiza

Afternoon Concurrent Session B1: BNF by tree legumes and fallow systems
Chairperson: *Dr. Edmundo Barrios*

1400 - 1420 Rhizobial inoculation improves plant growth and productivity in saline and dry conditions. *Dioumacor Fall*
1420 - 1440 Measuring biomass production and nitrogen fixation in fodder trees on smallholder farms in Kenya. *Benjamin Kibor*
1440 - 1500 Use of indigenous and improved legume green manures for improving maize yields in Tanzania. *Fabian Bagarama*
1500 - 1520 Coppicing tree legumes intercropped with maize on a clay soil in Zimbabwe. *Grace Mafaune Kanonge*

1520 - 1540 Health break and poster viewing. Poster presentations C33 to C51

1540 - 1600 Multi-functionality of agroforestry systems; Can integration of trees and crops contribute to enhance agricultural productivity, resource utilization and livelihoods for smallholder farmers? A quantitative approach. *Ingrid Öborn*
1600 - 1620 Drivers of rhizobial diversity in soils of smallholder farms in Malawi. *Anne Turner*
1620 - 1640 Agroforestry: An alternative soil fertility paradigm. A case of soil fertility management in Western Kenya. *Nelson Mango*
1640 - 1700 Discussion on BNF by tree legumes and fallow systems

Afternoon Concurrent Session B2: BNF by grain legumes
Chairperson: *Dr. Paul Mapfumo*

1400 - 1420 Effect of planting time on soybean yield and biological nitrogen fixation in Southern Rwanda. *Ruganzu Vicky*
1420 - 1440 Effect of N, P and inoculation on growth, nodulation, N_2 fixation and yield of promiscuous and non-promiscuous soybean. *Carlos Muananamuale*
1440 - 1500 Legume response to inoculation with rhizobium in Kivu, DR Congo. *Masamba Walangululu*
1500 - 1520 Effect of planting density on yield of a soybean-maize intercrop in Western Kenya. *Margarida Simbine*

1520 - 1540 Health break and poster viewing. Poster presentations C33 to C51

1540 - 1600 Strategies for enhancing common bean productivity in Kenya. *Catherine Kibunja*
1600 - 1620 Organic production of cowpea in mixed culture with sorghum. *Tenebe Ado*
1620 - 1640 Plant density and mineral fertilizer affect groundnut yield in Northern Mozambique. *Henriques Colial*
1640 - 1700 Discussion on BNF by grain legumes

Afternoon Concurrent Session C: Theme 3: Exploring options for sustainable intensification and diversification of farming systems (continued)
Chairperson: *Dr. Daniel Mugendi*

1400 - 1420 Effects of soil and water conservation techniques on run-off, sediment yield and maize productivity. *Felix Ngetich*
1420 - 1440 The potential application of ISFM principles in improving rice production in lowland rainfed and irrigated ecologies of East Africa. *Nhamo Nhamo*
1440 - 1500 Labour burden, not crop productivity, increased under no-till planting basins on smallholder farms in Murehwa district, Zimbabwe. *Leonard Rusinamhodzi*
1500 - 1520 Building fertilizer recommendations to support ISFM. *Adrian Johnston*

1520 - 1540 Health break and poster viewing. Poster presentations C33 to C51

1540 - 1600 Effect of long term fertilizer application on striga density. *Sibusisiwe Kamanga*
1600 - 1620 Response of teff (*Eragrostis teff*) to Zn fertilization on vertisols in Etiopia. *Bereket Haileselassie*
1620 - 1640 Towards implementation of fertilizer recommendations: assessment of crop limiting nutrients and appropriate nutrient rates. *Generose Nziguheba*
1640 - 1700 Beyond ISFM: A market driven approach to profitable, sustainable farming. *John Wendt*
1700 – 1720 Discussion on exploring options for ISFM

1700 - 1900 Launch of *"Africa Soil Health Consortium: Handbook for Integrated Soil Fertility Management"* in exhibition area (find additional details on page 16).

Wednesday, 24 October

Participants may chose from three excursions:

Excursion 1. Nairobi Park

Nairobi National Park is a unique ecosystem by being the only protected area in the world close to a capital city. The park is located only 7 km from Nairobi city centre. This savannah ecosystem is comprised of different grassland, bush and forest vegetation types. Open grass plains with scattered acacia bush are predominant. The western side has a highland dry forest and a permanent river with a riverine forest. To the south are the Athi-Kapiti Plains and Kitengela migration corridor which are important wildlife dispersal areas during the rainy season. Man-made dams within the park have added a further habitat, favorable to certain species of birds and other aquatic biome. Major wildlife attractions are the Black rhino, lion, leopard, cheetah, hyena, buffaloes, giraffe, zebra, wildebeest, elands and diverse birdlife with over 400 species recorded. Other attractions include the Ivory burning site Monument, Impala Lookout and the walking trails at hippo pools. The excursion will depart Safari Park Hotel at 0800, is conducted by area tour operators. See Secretariat for further details.

Excursion 2. Inoculant production and fertilizer blending in Nakuru by MEA Fertilizers Ltd.

This excursion starts from the Safari Park Hotel at 0830 and proceeds to Nakuru in the Great Rift Valley (travel time 2 hours). It stops at MEA Ltd (K) for tours of the BIOFIX inoculant production, Sympal fertilizer blending and the commercial soil analysis laboratory (2 hours). It then proceeds to scenic Lake Naivasha, and its large commercial greenhouses, for a lakeside picnic lunch (1 hour) and back to Nairobi via the "old Naivasha Road" up the Rift Escarpment (1.5 hours) to the University of Nairobi MIRCEN lab and greenhouse facility (1.5 hour). The tour then ends at Safari Park Hotel (30 minutes) returning at 1730. The Excursion is led by Ms. Teresah Wafulah (MEA Fertilizer) and Prof. Nancy Karanja (UoN MIRCEN). See Secretariat for further details.

Excursion 3. Commercial farming in Naivasha

This excursion will start from Safari Park Hotel at 0830 and proceed to Lake Naivasha. We will visit Finlays Horticulture Kenya Limited for tours to the cut flower glasshouses, export vegetable production systems, certified organic farm and Dudutech biocontrol product factory and quality control centre. This will then proceed for a picnic lunch (1 hour) at the scenic Lake Naivasha followed by a drive through the Hell's Gate National Park, with stopovers at selected points for game viewing and photo taking but there will not be sufficient time to walk down the famous Devils' Gorge . The Safari will then traverse through one of Africa's major Geothermal fields and then return to Nairobi through the old Naivasha Road to end at the Safari Park Hotel. See Secretariat for further details.

Thursday, 25 October

Morning Plenary Session and poster viewing

0850 - 0900	Conference announcements and plenary opening. Chairperson: *Dr. Peter Okoth*
0900 - 0940	Theme 5 Keynote Address: Commercialization of breakthrough ISFM technologies – what, how, who and when? *Teresah N. Wafullah*
0940 - 1020	Theme 6 Keynote Address: Diversifying and strengthening the capacity base for ISFM in Africa. *Dr Shaukat Abdulrazak*
1020 - 1040	Discussion on Theme 5 and 6 Keynote Addresses (short statements and questions)
1040 - 1120	Health break and Poster Session Themes 5 and 6 in Jambo Lobby. Poster presentations C61 to C85

Morning Concurrent Session A: Bio-prospecting tools, strain selection and delivery
Chairperson: *Sacko Ousmane*

1120 - 1140 Molecular tools for tracing arbuscular mycorrhizal fungi and plant growth-promoting rhizobacteria. *Natarajan Mathimaran*
1140 - 1200 Inoculation of legumes and its outcome on soil bacterial dynamics in potato cropping systems. *Trabelsi Darine*
1200 - 1220 Production of plant growth regulators and crop yield promotion by phosphate rock solubilizing *Bacillus. Lamine Traore*
1220 - 1240 Restoration of natural regulatory mechanisms of plant parasitic nematodes in intensively cultivated land. *Peter Wachira*
1240 - 1300 Discussion on bio-prospecting tools, strain selection and delivery

Morning Concurrent Session B: Rhizobial bio-prospecting, strain selection and inoculant delivery
Chairperson: *Dr. Abdullahi Bala*

1120 - 1140 Genetic and symbiotic diversity of rhizobia in Ethiopian soils: An untapped biological resource. *Endalkachew Wolde-meskel*
1140 - 1200 *Sinorhizobium americanum* symbiovar *mediterranense* is a predominant symbiont of common bean in Northern Tunisia. *Bacem Mnasri*
1200 - 1220 Effectiveness of rhizobia isolates from Kenyan soils in nodulation of soybean. *Maureen Waswa*
1220 - 1240 Improving nodulation and nitrogen fixation of promiscuous soybean through inoculation with commercial rhizobia inoculants. *Moses Thuita*
1240 - 1300 Discussion on rhizobial bio-prospecting, strain selection and inoculant delivery

Morning Concurrent Session C: Theme 4: Identifying bottlenecks and opportunities for implementation of ISFM

1120 - 1140 Introduction to Theme 4. Chairperson: *Dr Ademola Braimoh*
1140 - 1200 Agricultural technology performance among farmers in Central Africa. *Eliud Birachi*
1200 - 1220 Characterizing markets for soil fertility and land management in the grain basket areas of Kenya. *Mercy Kamau*
1220 - 1240 Determinants of adoption of soil erosion control technologies in Mt Elgon highlands in eastern Uganda. *Mildred Barungi*
1240 - 1300 Partnering in agricultural technology dissemination: a comparative case study of N2Africa partner organizations. *Judith de Wolf*

1300 - 1400 Lunch

Afternoon Concurrent Sessions A, B and C

Afternoon Concurrent Session A. Theme 5 Commercializing breakthrough technologies
Chairperson: *Dr. James Kahindi*

1400 - 1420 The commitment to agricultural production by MEA Limited, a leading farm input supplier *Teresah Wafulah*
1420 - 1440 Smallholder engagement in Kenya's emerging soybean industry. *Paul Woomer*
1440 - 1500 Embracing the market-led approach to drive the ISFM agenda: lessons from working with Soybean Resource Centers in Western Kenya. *Edgar Kadenge*
1500 - 1520 Impact assessment of soybean processing and marketing by Soybean Resource Centers in western Kenya. *Franklin Mairura*

1520 - 1540 Health break and poster viewing. Poster presentations C86 to C102

1540 - 1600 Putting Indigenous *Bradyrhizobium* strains to work for farmers in Kenya: Soyabean N credit to maize. *Victor Wafula Wasike*
1600 - 1620 Incidence and management of plant–parasitic nematodes under continuous vegetable production in Nigeria. *Adekunle Ojo*
1620 – 1640 Restoration of natural regulatory mechanisms of plant parasitic nematodes in intensively cultivated land. *Peter Wachira*
1640 - 1700 Discussion on market-led approaches for ISFM

Afternoon Concurrent Session B: BNF in an Interdisciplinary Context
Chairperson: *Dr. Felix Dakora*

1400 - 1420 Double inoculation of common bean with arbuscular mycorrhizal fungi and rhizobia. *Ahmed Qaddoury*
1420 - 1440 Effect of inoculating cowpea plants with rhizobium strain Tut53b2vu on N2 fixation, yield and nutrient uptake. *Flora Pule-Meulenberg*
1440 - 1500 Biochar alters plant growth and biological N fixation of common bean in Western Kenya. *David Guerena*
1500 - 1520 Performance of commercial bio-fertilizers on soybean production in Kenya. *Collins Majengo*

1520 - 1540 Health break and poster viewing. Poster presentations C86 to C102

1540 - 1600 Soybean performance resulting from different seed inoculation products in Kenya. *Margrate Mburu*
1600 - 1620 Virus infections: The major constrains for the productivity of grain legumes in symbiosis with rhizobia. *Maria Luisa Izaguirre-Mayoral*
1620 - 1640 Environmental, technological and food security characterization of cowpea cultivation in Mali. *Inamoud Ibny Yattara*
1640 - 1700 Discussion on BNF in a interdisciplinary context

Afternoon Concurrent Session C: Theme 4: Identifying bottlenecks and opportunities for implementation of ISFM (continued)
Chairperson: *Dr. Generose Nziguheba*

1400 - 1420 Farmer participatory development and evaluation of integrated striga and soil fertility management for cereal productivity in Sahelian and Sudanese zones of Mali. *Tom Van Mourik*
1420 - 1440 Which households are most likely to take up ISFM technologies and why? Case of Sidindi area, Western Kenya. *Elizabeth Nambiro*
1440 - 1500 ISFM use in bean production in southern Africa: the role of social and human capital. *Ruth Magreta*
1500 - 1520 The learning centre: a new approach to participatory technology development and dissemination in agriculture and natural resource management. *Paul Mapfumo*

1520 - 1540 Health break and poster viewing. Poster presentations C86 to C102

1540 - 1600 Understanding the dynamics of agricultural technology adoption: ISFM in South Kivu, DR Congo. *Isabel Lambrecht*
1600 - 1620 The role of researchers in bridging information gaps between farmers, extension agents and policymakers for improved food production in Africa. *James Kung'u*
1620 - 1640 Will ISFM alone realize the green revolution for Africa? *Peter Okoth*
1640 - 1700 Discussion on identifying bottlenecks and opportunities for ISFM

Friday, 26 October

Morning Concurrent Business Meeting and Thematic Writing Groups

0900 - 1040 AFRINOM Business Meeting. Convener: *Dr. Joyce Jefwa*
0900 - 1040 AABNF 15 Business Meeting. Convener: *Prof. Nancy K. Karanja*
0900 - 1040 AFNET Business Meeting. Convener: *Dr. Koala Saido*
0900 - 1030 Conference statement group convenes. *Convener: Dr Kristina Roing*

1040 - 1120 Health break and poster viewing. Poster presentations D1 to D20

1120 - 1300 Thematic breakout groups (6) prepare short statements

1300 - 1400 Lunch

Afternoon Plenary: FAO Policy Forum and Conference Statement

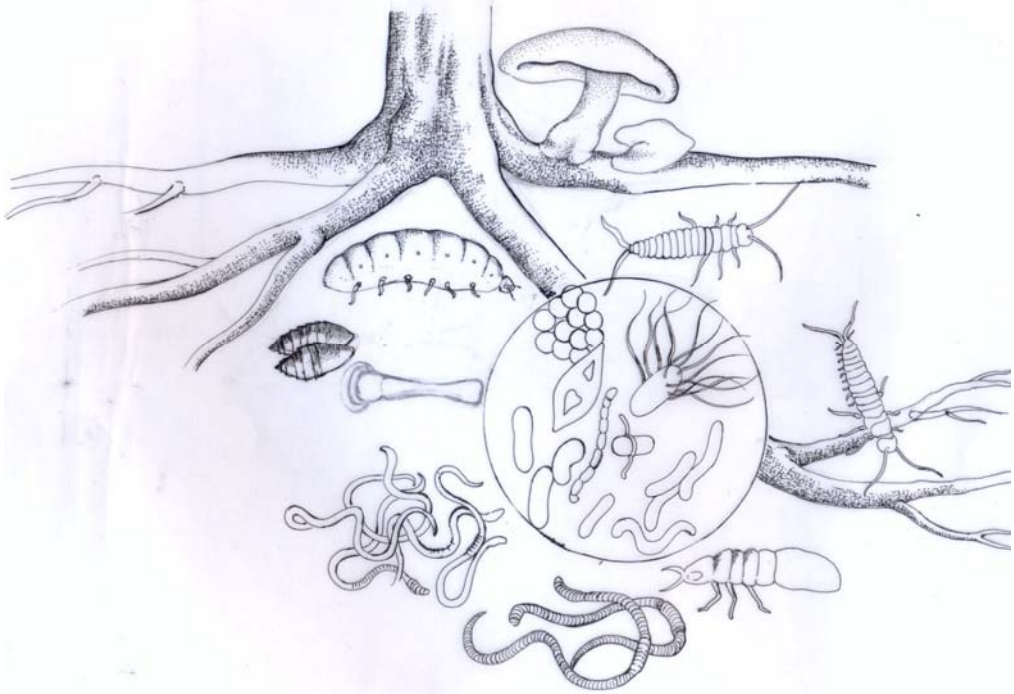
1400 - 1415 Opening of FAO Policy Forum. Convener: *Dr. Saidou Koala*
1415 - 1430 Policy dimensions of ISFM
1430 - 1510 Panel discussion of ISFM policy interventions
1510 - 1540 General discussion on ISFM policies

1540 - 1620 Health break and poster viewing. Poster presentations D21 to D28 and E1 to E5

1620 - 1640 Closing Plenary. Conference Statement ratified
1640 - 1700 Closing ceremony

☞ Special Exhibit and Book Launch ☜

The Soil Health Consortium will launch *"Handbook for Integrated Soil Fertility Management"* in the Jambo Hall lobby from 1700 to 1900 on Tuesday evening 23 October. This electronic book is edited by Dr. Thomas Fairhurst and contains contributions from many of the participants in the ISFM Africa 2012 Conference. Copies of the handbook and an accompanying video will be available to all participants. Refreshments will be served.



Conference Posters

Poster Sessions in Jambo Hall Lobby adjacent to coffee and tea service stations

Session A. Theme 1: Advancing plant-microbe interactions in crop nutrition

A1 Quality assurance of BIOFIX inoculants in Kenya. *Stanley Kisamuli*
A2 Effectiveness of marketed arbuscular mycorrhizal fungi inoculants on a breed soybean in Kenya. *Faye Aliou*
A3 Combined inoculation of commercial microbial and chemical products on survival and growth of tissue cultured banana in soils from different agro-ecological zones in Kenya. *Ruth Mukhongo*
A4 Testing for cassava market integration in the Democratic Republic of Congo. *Paulin Njingulula Mumbeya*
A5 Influence of mycorrhizal helper bacteria on arbuscular mycorrhizal fungi. *Joanna Dames*
A6 Indigenous arbuscular mycorrhizal fungi associated with the rhizosphere of cowpea in contrasting agro-ecological zones of Benin. *Johnson Jean-Martial*
A7 Effect of direct arbuscular mycorrhizal fungi inoculation on ex-situ colonisation and performance of maize and common bean in the Kenyan highlands. *John Nyaga*
A8 Isolation and characterization of endomycorrhizal spores from the rhizosphere of groundnut *Bouhraoua Dris*
A9 Response of *Acacia senegal* seedlings and soil bio-functioning to inoculation with arbuscular mycorrhizal fungi, rhizobia and *Pseudomonas fluorescens. Ndoye Fatou*
A10 Bio-intensity and agronomic intervention for enhanced crop productivity and mitigation of climate change. *Tenebe Ado*
A11 Seasonal variation and vertical distribution of mycorrhiza of *Pinus caribaea* in Uganda. *Kenneth Opiro Lakuma*
A12 Beneficial effect of *Pseudomonas* spp isolated from the rice fields in northwest Morocco. *Saida Aarab*
A13 Effects of mycorrhizal infection on bean and tomato cropping systems in Kivu Province, DR Congo. *Théodore Munyuli*
A14 Mycorrhiza can be better component of ISFM practices in weathered soil. *Bagula Mukengere Espoir*.
A15 In vitro spore germination of Tunisian truffle. *Amina Hamza*
A16 Maize production as influenced by earthworm-based integrated soil fertility management in tropical agro-ecosystems. *M. Amauth*
A17 Influence of a blended fertilizer and other sources of NPK on growth and yield of maize in Central Kenya. *Peter Mwangi*
A18 An example application of landscape planning and management tool designed to tackle land and water degradation. *Lulseged Tamene*
A19 Effect of eucalyptus amendment on soil chemical proprieties, enzymatic activity, acacia growth and symbiosis. *Abdoulaye Soumare*
A20 Can commercial microbial inoculants and new foliar fertilizers increase groundnut nutrient uptake and yield in a low fertility soil in a Sudanese Savanna. *Clement O. Ncho*
A21 Efficiency of *Bradyrhizobium japonicum* in different formulations and when co-inoculated with *Bacillus subtilis* on soybean in a Kenyan soil. *Mary Atieno*
A22 Effects of mycorrhizal infection on bean and tomato cropping systems in Kivu Province, DR Congo. *Theodore Munyuli*

Poster Session B. Theme 2: Enhancing biological nitrogen fixation in African smallholds

B1 Does inclusion of legumes in cereal cropping systems result in positive nitrogen balance? *Tonny P Tauro*
B2 Chickpea and lentil nodulating rhizobia indigenous to Ethiopia outperform imported commercial inoculants. *Endalkachew Wolde-Meskel*

B3 Response of wheat to fixed nitrogen by preceding faba bean and applied P in Ethiopia. *Amsalu Nebiyu Wold*ekirstos
B4 Effect of NPK micro-dosing on nitrogen fixation of groundnut and cowpea in the Sahel. *Addam Kiari Saidou*
B5 Long-term productivity of maize and pigeon pea systems in Malawi. *Donwell Kamalongo*
B6 Evaluation of plant growth and grain yield of 30 cowpea genotypes in Mozambique. *Abudo Rachad Ussene*
B7 Diversité et nodulation des legumineuses sauvages de la forêt équatoriale, RD Congo. *Neville Mapenzi*
B8 Effect of inoculating soybean on biological N_2 fixation and overall farm condition in eastern DR Congo. *Bigabwa Janvier*
B9 Symbiotic effectiveness of rhizobia in smallholder soyabean production of Zimbabwe. *Tatenda T Kainga*
B10 Effects of phosphorus sources and starter nitrogen on soil properties and soybean yield in the Central Highlands of Kenya. *Jackson Abuli*
B11 Improving maize yield through use of *Mucuna pruriens* and lablab at Kibondo and Kasulu Districts, Western Tanzania. *Peter Matata*
B12 Cowpea inoculation for improved yields in smallholder farms in Kenya. *Samuel Mathu*
B13 Scaling up of soybean production by smallholder farmers in Zambia: The case of Miracle Project. *Therese Gondwe*
B14 African traditional vegetables as an alternative source of nitrogen. *Max Muniafu*

Poster Session C. Theme 3: Exploring options for sustainable intensification and diversification of farming systems

C1 Use of integrated nutrient management in Alfisols and Ultisols to enhance maize-bean production among smallholder farmers in Western Kenya. *John Achieng*
C2 The role of bio-intensive technology in minimizing the contributions of traditional agricultural practices to climate change. *Michael Petu-Ibikunle*
C3 Effects of nutrient amendments on growth, grain yield and *Cecospora* leaf spot disease resistance of groundnut in northern Ghana. *Benjamin Ahiabor*
C4 Utilizing soil fertility replenishment measures for nutrient use efficiency in maize production. *Susan Alwang'a*
C5 On-farm adoption of under-utilized indigenous vegetable production among smallholder farmers in Nigeria: Implication for economic empowerment and genetic conservation. *Oyedele Durodoluwa*
C6 Relationship between phosphorus status and nitrogen fixation by common beans under drip irrigation. *Attar Hesham*
C7 Impact of adopting improved rice varieties on farmers' gross margin: Evidence from Nigeria. *Awotide Bola*
C8 Promouvoir les agricultures fragiles par la gestion intégrée des eaux et sols dans les agrosystèmes du nord Bénin. *Baco Mohamed Nasser*
C9 Contributions of N2-fixing legumes to soil fertility improvement: Opportunities for integrated management of soil fertility. *Vincent Bado*
C10 Évaluation des variétés de soja et leurs introduction dans le Sud-Kivu pour lutter contre la malnutrition et l'infertilité du sol. *Faustin Bafunyembaka*
C11 *Canavalia brasiliensis* brings a new horizon in agriculture in the semi-arid Tabora Region in Tanzania. *Fabian Bagarama*
C12 The effect of no-tillage practice on soil fertility in Tunisia. *Bahri Haithem*
C13 Matching the need for biological nitrogen-fixing grain legumes with most appropriate varieties: Evidence from East and Central Africa. *Frederick Baijukya*
C14 Agroforestry and soil health: Linking trees, soil biota, and ecosystem services. *Edmundo Barrios*
C15 Potential of grain legume fallows to improve household food security and financial returns: Lessons from a pigeon pea trial in Western Kenya. *James Mutegi*
C16 Nitrogen mineralization after combined and separate addition of compost and fertilizer in on-farm experiments in the highlands of Ethiopia. *Erik Karltun*

C17 Changing use of natural resources supporting smallholder farming communities and implications on climate change adaptation in Zimbabwe. *Christopher Chagumaira*
C18 Conservation agriculture based on direct drilling offers opportunity in Tunisia. *Hatem Cheikh M'hamed*
C19 Effect of organic and inorganic fertilizers on the yield of maize, common bean and soybean intercrops in Mozambique. *Oscar Chichongue*
C20 Meta-analysis of fertilizer use response across maize production systems in Sub-Saharan smallholder landscapes. *Stephen Ichami*
C21 Effects of *Jatropha curcas* monoculture in Senegal on the growth and symbiotic status of local symbionts. *Amadou Dieng*
C22 Producing microbial inoculants for eco-agriculture in Central Africa. *Dieudonné Nwaga*
C23 Analyse socioéconomique des stratégies de conservation de l'eau et des sols au Nord-ouest du Bénin. *Janvier Egah*
C24 Innovation in soil fertility for agro-forestry management in sub-Saharan Africa. *Elemide Oyebola Adebola*
C25 Millet yield and soil properties as affected by long-term application of fertilizer micro-dosing in the fragile millet-based system of the Sahel. *Fatondji Dougbedji*
C26 Integrated genetic and nutrient management options to raise pearl millet productivity under smallholder farmer conditions. *Hakeem A. Ajeigbe*
C27 Mehlich-III P soil test as a predictor of maize yield response to composted cattle manure. *Melissa Herman*
C28 Fertilité des sols et agriculture urbaine: le cas de l'usage du compost dans l'activité maraîchère. *Bertrand Joel Foe Eloundou*
C29 Response of maize to different soil fertility and water harvesting management options in semi-arid Eastern Kenya. *Cyrus Githunguri*
C30 Residual effects of organic soil inputs of contrasting quality on maize yield in the highlands of Western Kenya. *David Guerena*
C31 'Intensificationability': the potential to intensify for households growing rainfed crops on small farms. *Dave Harris*
C32 Nitrogen retention during composting with biochar. *Rachel Hestrin*
C33 Varietal and nitrogen effects in reducing *Striga hermonthica* seed bank and improving soil fertility in Western Kenya. *Geoffrey Kimuati*
C34 Nutrient uptake potential of selected under-utilized vegetables of Southwestern Nigeria. *Oyedele Durodoluwa*
C35 Nutrient management practices for vegetable production in smallholder crop-livestock farming systems in the peri-urban areas of semi-arid Eastern Kenya. *Justus Itabari*
C36 Establishment of a promotional program treating pollution in arable lands of Mali. *Fallaye Kante*
C37 Bio-fortified bean genotypes under integrated soil fertility management in the humid tropics soil of Democratic Republic of Congo. *Lubobo Kanyenga*
C38 Organic versus conventional farming: maize and baby corn yields in a comparative study in Central Kenya. *Edward Karanja*
C39 Soil salinization in selected irrigation schemes in semi-arid lands of Taveta County, Kenya. *Peter Kathuli*
C40 Integrated soil fertility management strategies for improved crop production in Kenya. *Catherine Kibunja*
C41 Intensification of maize systems with leguminous trees and shrubs for improved crop yield and wood supply in semi-arid Tanzania. *Anthony Kimaro*
C42 Approaches towards effective integrated soil fertility interventions in smallholder farms of Central Kenya. *Jeremiah Kimigo*
C43 Evaluating benefits of ISFM use in new maize and green gram varieties by smallholder communities in the semi-arid Kenya. *Lawrence Kimotho*
C44 Effects of different lime rates and liming methods on maize yields in Western Kenya. *Joel Kiplagat*
C45 Reduction of P sorption capacity in cocoa growing soils by use of integrated fertilization in Cote d'Ivoire. *Louis Koko*

C46 Managing maize yield gaps and profitability through efficient targeting of nutrients on light-textured soils in sub-humid environments. *Natasha Kurwakumire*
C47 Nitrogen content and its uptake by two maize hybrids in soils amended with lime, rock phosphate and farm yard manure. *Richard Onwonga*
C48 Assessing the influence of trees on soil macrofauna and soil properties in agricultural landscapes of Tanzania. *David Lelei*
C49 Soil fertility management strategies for priority seed propagated crops in Machakos and Bungoma: Climate change adaptation lessons. *Fredah Maina*
C50 Effects of integrated soil fertility management practices on soil hydraulic properties in Beseku, Ethiopia. *Eric Karltun*
C51 Zinc fertilization, maize productivity and grain quality under integrated soil fertility management in smallholder farming. *Grace Manzeke Muneta*
C52 Maize response to mineral N, P, K, manure and lime amendments in acid soils of the highlands of Central Burundi. *Marie-Chantal Niyuhire*
C53 The potential of maize-cowpea intercrops to increase crop productivity under reduced tillage in the semi-arid areas of Zimbabwe. *Justice Nyamangara*
C54 Effect of maize–soybean intercropping patterns on yields and soil properties in the Central Highlands of Kenya. *Jossias Matusso*
C55 Upscaling low input smallholder farming systems in rural Sub-Saharan Africa. *Richard Mbithi*
C56 Physiological characteristics of rhizobia isolated from *Retama raetam*) and *Lupinus various* indigenous to the Libyan desert. *Mohamed Salah Hassan*
C57 Response of common legumes in Zimbabwe to application of different fertilizer amendments. *Talkmore Mombeyarara*
C58 Influence of repeated application of high and low quantities of different quality organic amendments on soil fertility parameters and maize yield on a sandy-loam in Zimbabwe. *Jackson Mtangadura Tongai*
C59 Organic inputs and mineral fertilizer effects on soil chemical properties, soil water content and maize productivity in Mbeere District, Kenya. *Monicah Mucheru-Muna*
C60 Yield responses and profitability of soybean and maize production under different soil amendment options in south-western Uganda. *Joseph Mudiope*
C61 Effect of soil input application on yields of soybeans and climbing beans in a maize-legume rotation in Central Kenya. *Jayne Mugwe*
C62 Groundnut production as influenced by row planting methods and irrigation frequency in a Sudanese savanna. *Aisha Abubakar Mukhtar*
C63 Variation of nutrient content in soils of South Kivu, DR Congo. *Janvier Mulumuna-wa-Lola*
C64 Within-farm soil fertility variation in East African smallholder farms. *Anne Muriuki*
C65 Knowledge, attitude and practices of striga control in maize producing farms among small-scale farmers in Western Kenya. *Godfrey Nambafu*
C66 Relative effectiveness of agricultural lime and local lime materials in reducing soil acidity in Burera District, Rwanda. *Athanase Nduwumuremyi*
C67 Application of DNDC model to maize cropping systems under organic and mineral fertilizers management practices in Western Kenya. *Crispus Njeru*
C68 Soil and potato nitrogen status and use of the SPAD meter in nitrogen management in Kenya. *James Njeru*
C69 Impact of trees on water and nutrient dynamics in smallholder maize-based farming systems in Western Kenya. *John Nyaga*
C70 Variation of soybean varieties in nitrogen fixation and management of *Striga hermonthica* in Western Kenya. *Patrick Obasanjo*
C71 Impact of soil fertility management practices on major insect pests and yield of beans in Taita District, Kenya. *Willis Ochilo*
C72 Agronomic and financial analysis of maize-legume intercropping systems in Western Kenya. *Martin Odendo*
C73 Influence of phosphorus on selected soil dynamics in a desmodium-maize based cropping system in Western Kenya. *Henry Ogola Aloo*

C74 Establishing the most limiting major nutrient in two soils within the semi-deciduous forest zone of Ghana based on maize growth and yield. *Okebalama Chinyere*
C75 Effects of selected soil and water conservation techniques on rainfall use efficiency and maize productivity in the Central Highlands of Kenya. *Irene Okeyo*
C76 The effect of tillage, crop residue application and crop rotations on soil organic matter dynamics and soil microbial biomass in Western Kenya. *Jeremiah Okeyo*
C77 Effectiveness of liming and phosphorus fertilizer on maize production in acid soils of Western Kenya. *Violet Omenyo*
C78 Farmers' coping mechanisms and effectiveness of inorganic fertilizers on *Striga hermonthica* control in maize cropping systems of eastern Uganda. *Justine Onyinge*
C79 Water use efficiency of selected under-utilized indigenous vegetables as affected by seed density and spacing. *Oyedele Durodoluwa*
C80 Potential for changing traditional soil fertility management systems in a Rhodic Ferralsol in south Benin. *Pascal Houngnandan*
C81 Effects of soil ecosystem engineers on soil aggregate stability, soil C and crop yields under different tillage and residue management systems. *Paul Birthe*
C82 Long-term effects of land-use on soil properties in the Ethiopian highlands. *Erik Karltun*
C83 The quality of cover crops in no-till systems influences soil biological function. *Rabary Bodovololona*
C84 Managing soil fertility and timing of agronomic operations of diverse cereal crops for enhanced food self-sufficiency under increasingly variable climate in Zimbabwe. *Rurinda Jairos*
C85 Combination of lime, organic matter and fertilizers to foster the productivity of acidic soils of Southern Rwanda. *Pascal Rushemuka*
C86 The abundance and diversity of legume-nodulating rhizobia in 28 year-old plantations of tropical, subtropical and exotic tree species: a case study from Senegal. *Sène Godar*
C87 Finding niches for drought tolerant, short-season lablabs in semi-arid farming systems of Eastern Africa. *Anne Sennhenn*
C88 Integrated nutrient management in Indo-Gangetic plains improved total microbial activity of soil under a rice-wheat cropping system. *Pankaj Sharma*
C89 Soil characterization in contrasting cropping systems under the fast track land reform program in Zimbabwe. *Shoko Munashe*
C90 Effect of tied-ridging and enhanced soil fertility on maize yields in the semi-arid north Rift of Kenya. *Joseph Sitiene*
C91 *Allanblackia*, a tree crop under current domestication: What are the soil requirements and important symbionts? *Dahlin Sigrun*
C92 Relative growth rate and its components for East African Highland Banana as affected by water, potassium and nitrogen supply in Uganda. *Godfrey Taulya*
C93 Bio-slurry and inorganic fertilizers effect soil properties and maize yield in Rwanda. *Olive Tuyishime*
C94 Exploring options to intensify soybean production with smallholders in Malawi. *Daniel van Vugt*
C95 Farmers' perception of climbing bean-based cropping systems in Rwanda. *Vicky Ruganzu*
C96 Effect of organic and inorganic fertilizers on leaf nutrient uptake and quality of tea. *Vivian Kekana*
C97 Restoration of natural regulatory mechanisms of plant parasitic nematodes in intensively cultivated land. *Peter Wachira*
C98 Enhancing maize productivity in smallholder irrigation systems under water and nutrient limiting conditions in southern Malawi. *Shamie Zingore*
C99 Land degradation and its implication for delineating management zones in smallholder systems of Western Kenya. *Boaz Waswa*
C100 Effect of inoculation time on growth of two banana genotypes inoculated with commercially produced arbuscular mycorrhizal fungi. *Gaidashova Sveta*
C101 Assessing tree effects on soil physico-chemical characteristics in agroforestry parklands of Burkina Faso. *Noel Coulibaly Yacouba*
C102 Placement profond de l'urée et amélioration de l'efficacité d'utilisation de l'azote en riziculture irriguée: cas du périmètre rizicole de Karfiguéla au Burkina Faso. *Poulouma Louis Yameogo*

Poster Session D. ***Theme 4: Identifying bottlenecks and opportunities for implementation of ISFM, and Theme 5: Commercializing breakthrough technologies***

D1 Bio-economic modeling for ex-ante assessment of economic policies for adoption of ISFM technologies to ensure food security and raise income of farm households in Rwanda. *Jean-Claude Bidogeza*

D2 A socio-economic analysis of the factors that affect legume production among smallholder farmers in Zimbabwe. *Dunjana Sibonginkosi*

D3 Exploring the relevance of the agro-input dealers suitability for disseminating and communicating soil fertility management practices: The case of Siaya and Trans Nzoia Counties, Kenya. *Brian Tiberious*

D4 Improving productivity of smallholder millet and sorghum based production systems in the semi-arid region of Northern Nigeria through integrated soil fertility management practices. *Jibrin M. Jibrin*

D5 Application of cluster techniques for soil fertility trial site selection and characterization in Eastern Kenya. *Peter Kamoni*

D6 Competitiveness of shelled groundnut markets in Central Malawi: A market integration approach. *Admire Katunga*

D7 Soil organic matter variability and its impact on maize yields in smallholder farms in Central and Eastern Kenya. *Catherine Kibunja*

D8 Client-focused extension approach for disseminating soil fertility management information in Central Kenya. *Serah Muchai Kimaru*

D9 A paradigm shift: Everlasting greening in the summer rainfall regions of Southern Africa. *Susan Koch*

D10 Using choice experiments for ex-ante assessment of ISFM adoption: An application to climbing beans in Burundi. *Isabel Lambrecht*

D11 Potential role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farming systems of Sub-Saharan Africa. *Jossias Matusso*

D12 Gender access to formal credit and its impact on micro- and small-enterprise growth in Western Kenya: Case study of Kakamega municipality, Kenya. *Mauyo Lianda*

D13 Profitability of soybean, climbing beans and maize rotation systems under varied integrated soil fertility management regimes in the Central Highlands of Kenya. *Nicholas Muba*

D14 A situational analysis of opportunities and challenges of using ISFM information and knowledge in Kenya. *Angela Ndanu*

D15 Using the Rasch model to explain farmers' behavior towards adoption of soil fertility management technologies in Kenya: The case of vegetable and cut-flower growers. *Kelvin Shikuku*

D16 Dry land small scale farming system: Wetland utilisation agricultural production and marketing in Upper Ewaso Ngiro Basin, Laikipia County, Kenya. *Caroline Ouko*

D17 Effects of organic and inorganic nutrient source on growth, total chlorophyll and yield of three bambara groundnut landraces in the coastal region of Cameroon. *Victor Desire Taffouo*

D18 Determinants of soybean market participation by smallholder farmers in Zimbabwe. *Byron Zamasiya*

D19 Land-care bylaws increase adoption of soil erosion control technologies: Evidence from the Mt. Elgon highlands of Eastern Uganda. *Mildred Barungi*

D20 Maize response to application of inorganic fertilizers, and manure in eastern and northern Uganda. *Kayuki C. Kaizzi*

D21 Tillage, legume and soil management effects on sorghum yield in Eastern Uganda**.** *Angella Nansamba*

D22 Improving acidic soils through application of agricultural lime and multi-nutrient fertilizer on smallholder farming systems of Western Kenya. *David Mbakaya*

D23 Scaling-out soil fertility amendments in western Kenya. *Martins Odendo*

D24 Integrating grain legumes in maize-based systems for improved soil healthy, food security and incomes by smallholder farmers in Zambia. *Laston Milambo*

D25 Effect of fertilizer micro-dosing on yields of intercropped maize and pigeonpea in Tanzania. *S.D. Lyimo*

D26 Exploring the effects of different fertilizers on yields and benefits of important crops grown in Kagera, Tanzania. *M. S. Merumba*

D27 Scaling up Minjingu phosphate utilization for balanced fertilization of crops in Tanzania. *J. M. R. Semoka*

D28 Effects of tillage, crop rotation, and nitrogen fertilization on maize and soybean under rain-fed conditions. *Isaac Savini*

Poster Session E. Theme 6: Building capacity in Integrated Soil Fertility Management

E1 The lead farmer approach: An effective way of agricultural technology dissemination? *Isaac Chabata*

E2 Support of the ARC-Plant Protection Research Institute to agriculture in South Africa and other African countries: Promotion of soil health and plant microbiology. *Susan Koch*

E3 Factors influencing ISFM knowledge in the Central highlands of Kenya. *Joseph Macharia*

E4 Promoting Integrated Soil Fertility Management within grassroots NGOs. *Alex Magaga*

E5 Impact of ICT in maize cultivation and agronomy: The case of the short text messages service to farmers in Western Kenya. *Peter Okoth*

ISFM Africa 2012 Abstracts (in alphabetical order)

Note that these abstracts appear in alphabetical order by presenter's surname. That presemter's name is underlined, and only their institutional affiliation and contact email appear. Some lengthy titles were shortened and abstracts edited. In some cases, authors that submitted an abstract before the conference deadline, but proved unable to participate in the conference are also included among these abstracts owing to the time required to compile, format and print these entries.

Beneficial effect of *Pseudomonas* spp isolated from the rice fields in northwest Morocco

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Several studies have adopted a new approach using biofertilizers composed by microorganisms present naturally in the rhizosphere to improve plant productivity while reducing input of chemical fertilizers. The objective of our work is the isolation and selection of rhizobacteria belonging to the genera *Pseudomonas* with beneficial activities in vitro to be used as inoculum for rice. Seven bacteria (PP7, PE76, PP17, PE77, PG1, PG70 and PP22), belonging to the genus *Pseudomonas*, were isolated from the rhizosphere of three rice varieties (Puntal, Elio and Guadiamar) and selected for their tricalcium phosphate-solubilizing ability. These strains were analyzed for production of siderophores, indole acetic acid (IAA), ACC deaminase and the capacity to fix nitrogen. To assess the effect of these rhizobacteria on rice growth, Puntal's seeds were inoculated and grown under glasshouse conditions for a month. Three growth measurements were recorded: shoot length, dry weight of shoot, and dry weight of root. The results show that all strains are able to produce sidérophores and IAA, but only two strains were capable of degrading ACC. All isolates were negative for fixing atmospheric nitrogen. For the effect of inoculation, only PG1, PG70 and PP22 showed an increase in the measured parameters by 50% and 10% respectively compared to the negative and the positive control. The other bacteria (PP7, PE76, PP17 and PE77) showed a decrease when compared to negative control. Our findings indicate that PG1, PG70 and PP22 have potential to promote rice growth through direct physiological mechanisms such as the production of phytohormones and sidérophores, and solubilization of phosphates. These bacteria offer a basis for a new biofertilzer in order to make rice cultivation sustainable and less dependent on P chemical fertilizer.

The effect of inoculation on the growth and yield of *Vigna unguiculata* under salt stress

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Agricultural production in the Mediterranean basin is limited by the environmental stresses such as salinity due to the arid and semi-arid climates which characterize this area. Symbiotic atmospheric nitrogen fixation is an effective ecological solution for the maintenance of durable agriculture in the Mediterranean but it must perform underthese stresses. Accordingly, we undertook to evaluate inoculation of a population of *Vigna unguiculata* L. walpers cultivated under constraint salt stress. Seeds of cowpea were inoculated by four rhizobium strains, two strains are slow growth developing until 0,2 M and two strains are rapid growth tolerating up to 0,4 M NaCl. Four levels of stress were applied: no stress, low stress, medium stress and high stress. The growth and the yield were recorded. Salinity affected the growth and the development of *V. unguiculata* but the inoculation made it possible to slow down the unfavorable effects of this stress. On the other hand, a better answer to the inoculation with the slow growth strains was observed. However the best fodder and yield were obtained at the plant dually inoculated with rapid growth and with slow growth strains, we also noted most nodules indicating a synergism between strains. The inoculation, particularly the dual inoculation, improved the tolerance of cowpea to salinity stress. Also it would be interest to supplement this study by tests in full fields in order to confirm these results.

Effects of phosphorus sources and starter nitrogen on soil properties and soybean yield in the Central Highlands of Kenya

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Farmers in Central highland Kenya continue to experience depressed land productivity and incomes mainly due to their farms' low soil fertility status. Fertilizer costs have remained high, beyond the reach of many farmers. Integrated soil fertility management (ISFM) is espoused as an appropriate intervention. Integration of legumes into smallholder farming system is one of the ISFM options. Symbiotic legumes can minimize nitrogen fertilizer requirements while improving farmers' incomes and food security. Soybean is a versatile legume fixing more nitrogen (N) than most grain legumes but its production has not received adequate attention in spite of its huge demand and short supply in the country. The most limiting nutrient in soybean production is phosphorus (P), critical in soybean growth and biological nitrogen fixation (BNF) but is limited in the Central Highlands, needing replenishment. For effective soybean growth, N is required before the crop can start fixing its own N. The study done at Kigogo in Meru South District and Kamujine in Tigania East District assessed sources of P, with or without starter N application. The sources of P were Triple Super Phosphate (TSP), Minjingu rock phosphate, Mavuno fertilizer, DAP, manure and fortified manure (Manure with Minjingu fertilizer at 1:1 ratio) all providing 30 kg P ha^{-1}. Diammonium Phosphate (DAP) was a reference input as it has both P and N. The trial was carried out in randomized complete block design (RCBD) having four

replications with a plot size of 4.0 m by 4.5 m, being done in two seasons. Data was analyzed using analysis of variance (ANOVA) and means separated using Least Significant Difference (LSD) (p=0.05). Using CAN with Mavuno fertilizer had the best yields. Results showed starter N enhanced soybean yields but with mixed results on BNF. Farmers have an alternative in Mavuno fertilizer which provides higher yields while supplying more nutrients than the recommended DAP.

Use of integrated nutrient management in Alfisols and Ultisols to enhance maize-bean production among smallholder farmers in western Kenya

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Maize (*Zea mays* L.) and beans (*Phaseolus vulgaris* L.) are important food crops in western Kenya, mostly grown by resource-poor farmers in complex and risky cropping systems. Trends in population growth in Kenya indicate that the demand for maize and beans is projected to increase ca. 3–4% annually, supporting a case for the sustainable intensification of maize and bean production. It is estimated that about 1.6 million hectares of land are under maize crop annually with 80% being grown by smallholder farmers, many of whom are in western Kenya. The average yield of maize is less than 1 t ha^{-1} instead of a reachable 6.0 t ha^{-1}, while yield of beans averages 0.2 t ha^{-1} instead of 0.6-1.0 t ha^{-1}, leading to vicious cycle of food insecurity and persistent poverty. Maize-bean production is hampered by the predominance of fragile ecosystems, low inherent soil fertility and low use of modern inputs, resulting in mining and depletion of the soils. In view of high costs of imported fertilizers, an on-farm experiment was conducted in two soil types (Alfisols and Ultisols) on 10 farms during long and short rains seasons in western Kenya to test whether Integrated Nutrient Management (INM) can enhance crop productivity among smallholder farmers. During long rains season, optimal fertilizer application in Alfisols gave maize grain yield of 9.1 t ha^{-1} compared to Ultisols' 6.6 t ha^{-1}. In the same season, farmyard manure 2 t + 30 kg N gave 5.3 t ha^{-1} in Alfisols and 3.9 t ha^{-1} in Ultisols. In both soils, yield from NPK (60 kg N + 60 kg P + 40 kg K) treatments were significantly higher than those of NP treatments, indicating that the soils were K deficient. Furthermore, yields from FYM treatment were comparable to those of NPK treatment. On the other hand, during the long rains season, FYM, NP (60 kg N + 60 kg P) and optimal fertilizer application in Alfisols gave the highest bean grain yield of 0.3, 0.3 and 0.4 t ha^{-1}, respectively. In Ultisols, FYM and optimal fertilizer gave highest bean grain yield of 0.8 and 0.2 t ha^{-1}, respectively. During short rains season, maize grain yield from optimal fertilizer in both soils were lower than in long rains season. Use of desmodium and stylosanthes as cover crops and tithonia mulch substantially reduced weed density. The most outstanding conclusion of this study is that application of K fertilizer substantially enhanced maize yield during long rains season. Even though the effect of K application was observed in both soils, it was more dramatic in Ultisols. This indicated that Ultisols were more K-deficient hence the need for its application. Use of farmyard manure and tithonia mulch gave significantly high grain yields, probably by mitigating the soil acidity. This suggests that use of either farmyard manure or tithonia mulch can sustainably be used by farmers whose soils are acidic in order to improve maize productivity.

Incidence and management of plant–parasitic nematodes under continuous vegetable production in a rainforest agroecology in Nigeria.

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Two separate farmers' vegetable fields approximately 11 x 17 m^2 in Ile-Ife, Nigeria located at latitude 070 28lN and longitude 04033lE at 244 m above sea level in the tropical rainforest were sampled for plant–parasitic nematodes which are common microscopic pests of vegetables. Prior to soil sampling, symptoms of nematode infection including yellowing of leaves, wilting and stunted plants were recorded in soil around the roots of *Telfaria occidentalis* planted in the farmers' fields. The first field A had been cropped continuously to vegetables for three years while the adjacent field was being planted to *T. occidentalis* for the second year. The fields were divided into eight equal plots each and soil samples were collected for nematode analysis. Plant-parasitic nematode population in field A was 1769-2066/ 200 ml soil while a population of 302-695/ 200 ml soil was recorded in field B. Given the relatively high soil nematode population in field A, compost was applied around the roots of the vegetable crop in the field at the rate of 10 t/ha, resulting in a reduction in population of phytonematodes by 30-50 % within three weeks of application. Plant nematodes identified in the two fields were *Meloidogyne incognita*, *Tylenchus* spp., *Helicotylenchus* spp., *Hirschmaniella* spp., and *Longidorus* spp. Plant parasitic nematodes are an extremely important limiting factor in vegetable production in intensive systems where mono-cropping is practised, hence there may be the need to formulate effective management strategy involving the use of organic fertilisers against the pest under such conditions and thereby bring nematode pest population under control as well as improve soil physical properties.

Influence of organic acids from ectomycorrhizal fungi on weathering of iron ore minerals

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Many studies had proposed that factors such as pH, nutrient limitation, grain size, organic acid production, and mechanical penetration of the mineral have different influences on mineral weathering. Of all these factors, production of organic acids is probably the most acknowledged. Ectomycorrhizal fungi have special capability to uptake nutrients from rocky and hard mineral

materials through production of low-molecular-weight HOC=O compounds known as organic acids. The present study examined the potential roles of organic acids produced by four ectomycorrhizal fungi on weathering of iron ore minerals. Low grade quality iron ore minerals from Sishen iron ore mine were utilised in this study in an experiment that involved both mycorrhizal and non-mycorrhizal *Pinus patula*. Four types of ECM fungi were used, namely *Pisolithus tinctorius*, *Paxillus involutus*, *Laccaria bicolor* and *Suillus tomentosus*. After harvest, the organic acids contents of the soil were analysed using high-pressure liquid chromatography (HPLC). Four different organic acids content of the soil that included oxalic acid, citric acid, malonic acid and maleic acid were analysed. Among the organic acids analysed from the soil samples in this study, citric acid was the highest produced, followed by oxalic acid. Neither the nutrient limitation nor the addition of iron ore minerals increased organic acid production by both mycorrhizal and non-mycorrhizal plants. With no statistically significant difference between the amount of citric acid detected in treatments with highest and lowest potassium mobilisation, the quantity of organic acid produced in the present study can therefore, not be directly correlated to mobilisation of either P or K from the iron ore minerals. This suggests that mineral weathering occurred as a result of combination of factors not only in response to organic acid production by the ectomycorrhizal fungi. The study has also shown that whether mycorrhizal or not, pine roots are able to mobilise nutrients from iron ore minerals. However, depending on the species, mycorrhizal plants can be more effective in nutrient mobilisation compared to non-mycorrhizal plants.

Organic production of cowpea in mixed culture with sorghum

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A three year trial was conducted with the main objective of achieving optimum cowpea grain yield without stater mineral N and inorganic pesticides. Three spatial arrangements were tested against three weeding regimes. The experiment designed was factorial combination of the treatments laid in Completely Randomised Block. The treatments were replicated thrice. The effects of these cultural interventions were observed on cowpeas' srtiga count, days to maturity, nodulation, net assimilation rate (NAR) and grain yield. Data collected were subjected to ANOVA and means were using LSD ($P \leq 0.05$). Early maturity in cowpeas and NAR were significantly ($P \leq 0.05$) enhanced by the interaction of weeding regime and spatial arrangement. Weeding × spatial arrangememt significantly ($P \leq 0.05$) reduced striga incidence on cowpea during years 2003 and 2004. Weeding thrice × sowing 1:2 and weeding twice × sowing same hill gave a statistically similar result. Nodulation was enhanced by the interaction of weeding regime and spatial arrangement. Weeding regime × spatial arrangement significantly ($P \leq 0.05$) increased cowpeas grain yield during year 2004 trial. The highest grain yields 1344 and1347 kg/ha were recorded from weeding twice × sowing 1:2 and weeding thrice × sowing same hill. Based on this resultes and the field observations, it was suggested that the frequency of weeding enhanced physical removal of weeds, minimised competion for growth resources, soil conditioning for optimum airation/ soil air:water ratio for optimun mycorrizer and other benefitial soil microbial activities. Intercropping afforded better canopy coverage for moisture conservation and pest control.

Agronomic intervention for enhanced crop productivity and mitigation of climate change

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This trial was conducted in the semi-arid zone of Nigeria. The main objective was to investigate the options that could improve crop yield with minimum damage to the ecosystem. A split-plot design experiment was laid with 3 irrigation methods in the main plots. The sub-plots were assigned to 3 bio-fertilizer materials. Data were taken on nodulation, root length, pod yield and seed protein content of green pea. Data were subjected to ANOVA, and means that were significantly different were separated using LSD (≤ 0.05). The result showed that green pea nodulation was significantly ($P \leq 0.05$) increased to 29, root length to 22.5 cm, pod weight was 16.68 kg and seed protein content to 6.0% by the series of possible interactions between the subsistence irrigation methods and bio-fertilizer agents. It was observed that subsistence irrigation methods can conserve water and improve soil-root water relationship to compliment the roles of bio agents in supplying required nutrients. It was concluded that the contributions of agronomy practices to climate change can be minimized via appropriate policy control of irrigation water wastage and the burning of bio-degradable materials. It was recommended that micro-organism activity could be promoted and used in enhancing improved crop productivity and gravity controlled drip irrigation method adopted to facilitate water conservation.

Growth, grain yield and *Cecospora* leaf spot disease resistance of groundnut in northern Ghana

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Leaf spots are the most common and serious diseases of groundnut in northern Ghana. Early leaf spot (ELS) and late leaf spot (LLS) diseases of groundnut (*Arachis hypogaea*) caused by *Cercospora arachidicola* Hori and *Cercosporidium personatum*, respectively are economically important foliar diseases in Ghana and can cause considerable yield losses of 50-70% in groundnut in West Africa through reduction of photosynthetic leaf surface and stimulation of leaflet abscission resulting in extensive defoliation. In Ghana, pod yields of groundnut crops remain low below 1.0 t ha^{-1}, which is far less than the potential yield of 2.0-3.0 t ha^{-1} thereby affecting groundnut production, the income and welfare of groundnut growers. It is not clear whether the problem of low yields in groundnut, especially in northern Ghana, is as a result of declining soil fertility (since

groundnut growers seldom apply any fertilizer to their crops) or *Cercospora* leaf spot disease infection or changes in climatic conditions. This study examined the effects of application of nutrient amendments on the growth, grain yield and *Cercospora* leaf spot resistance of Chinese, the most commonly grown groundnut variety in northern Ghana. The trials were conducted on-station at Nyankpala in the Guinea Savanna zone of Ghana. The Chinese was planted on ridged 4.2 m x 3.0 m plots at 60 cm x 20 cm at two plants per hill. Treatment combinations used were SSP (30 kg P/ha), TSP (30 kg P/ha), organic manure (4 t/ha) + TSP (30 kg P/ha) and organic manure (4 t/ha) + TSP (30 kg P/ha) + BoostXtra and a control treatment with no input. SSP and TSP were side-dressed and the organic manure (FertiSoil) incorporated into the soil one week before planting. The BoostXtra (a compound micronutrient formulation) was foliar-sprayed at two weeks interval beginning from 50% flowering till maturity. Both ELS and LLS disease severities and per cent defoliation were assessed using the ICRISAT Scale. The combined application of TSP and manure greatly enhanced haulm, shell and biomass dry weights and grain yield. The increased grain yield in this treatment can generally be attributed to increased seed size. Except seed size, these parameters were also increased when the TSP + Manure treatment received foliar sprays of BoostXtra producing a grain yield increase of 64%. Application of nutrient amendments significantly increased the tolerance/resistance of Chinese to leaf spot disease which subsequently reduced defoliation. Susceptibility of Chinese to leaf spot disease, resulting in low grain yields, can therefore increase in soils with low fertility but this can be averted by applying nutrient amendments to the crop.

Utilising soil fertility replenishment measures for nutrient use efficiency in maize production in Western Kenya

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Soil acidity and fertility depletion, particularly nitrogen (N) and phosphorous (P) deficiencies are major limitations to food production in Sub-Saharan Africa, including Kenya. The purpose of this study was to determine the nutrient use efficiencies in maize production in the main maize producing counties in Kenya; Trans-Nzoia, Uasin-Gishu and Siaya.The study was an on-farm experiment done at various farms, working with 10 farmers from each county, a total of 30 farmers. The rates of fertilizer applications were derived following the Kenya FURP recommendations, 75Kg N/ha plus 26Kg P/ha. The plots were arranged in an incomplete randomized block design and all the yield data subjected to one–way ANOVA. The initial soils characterization indicated that the soils were low in soil pH, available P (<10 mg P/kg), total N (<0.2%) and organic carbon (<4.0%). The Agronomic Nutrient Use Efficiency (ANUE) of nitrogen and phosphorous was found to be highest in DAP + lime at an average of 14.4 kg grain/kg P and 5.1 kg grain/kg N while it was lowest in Minjingu plots at an average of 11.6 kg grain/kg P & 4.0 kg grain/kg N though there was no significant effect ($p<0.05$). DAP + lime plot still gave the highest mean yields recorded at 5.56 tons/hectare while the Rotuba with ½ DAP plot gave the lowest yields among the plots with treatments at a mean of 4.83 tons/hectare. There was no significant difference in the yields of the treatments at $p<0.05$ but there was a significant difference between the treatments and the control plots which realized a mean of 1.75 tons/ha.

In vitro spore germination of *Terfezia boudieri,* Tunisian truffle

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Terfezia boudieri Chatin (locally know as black Kamé) in one of several genera and species of truffles in the family *Terfeziaceae* found in North Africa, Saudi Arabia, Iraq, Syria, Arabian Gulf States and other Middle East countries. It is a hypogeous fungus thought to from mycorrhiza with the annual *Helianthemum* spp. The edible fungus has considerable economic value for culinary use. Methods for its cultivation would yield high returns. Ascospores from both fresh and dried ascocarps germinated in the laboratory. Germination was faster for spores from dried specimens than for those from fresh specimens. Germinated spores in both cases underwent several morphological changes that are considered good indication of the germination process of this species.

On-farm adoption of under-utilized indigenous vegetable production among smallholders in Nigeria

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Indigenous vegetables are crops that are grown and consumed by the local farmers along with the arable crops to serve as means of protein, minerals and vitamins in the diet especially in the Southwestern region of Nigeria. These vegetables have suffered significant scientific exploitation and abandonment due to several social and economic factors, thus, these vegetables are threatened into extinction but have the potentials to enhance farmers' economic condition if integrated into the existing traditional farming system and also serve as forum of conservation. Adoption of some of these under-utilized indigenous vegetables into the cropping system of the smallholder farmers in southwestern Nigeria, using extension approaches was conceived, with a view to increasing farm income and conserve the vegetables which are endangered. Multi-stage participatory extension approach was used thus: a total of one hundred and fifty smallholder farmers were randomly selected from five States in the region alongside Fadama facilitators who were purposively selected for the project from the states. Demonstration plots of

the indigenous vegetables were also established along with the farmers plots for the development of improved agronomic methods training of participants on the cultivation methods, nutritional potentials, postharvest handling and processing was carried out. Other inputs were given to the farmers for the establishment of on-farm plots of indigenous vegetables. The project revealed a high knowledge of the nutritional potentials of some of the vegetables (*Telfairia occid*entalis (Ugu), *Curcubita pepo* (Elegede), *Solanum macrocarpon* (Igbagba), *Amaranthus viridis* (Tete atetedaye), *Solanecio biafrae* (Woorowo), *Trichosanthes cucumerina* (Snake tomato), *Vernonia amygdalina* (Bitter leaf) and Ajefawo, but low agronomic and cultivation knowledge of some like *Crassocephalum crepidoides* (Ebolo), *Solanum nigrum* (Odu) and *Solanum sp*. (Ogumo). Performances of the on-station and on-farm plots significantly showed the economic potentials of the vegetables and served as ex-situ means of conservation. Lack of agronomic and cultivation knowledge of some of the vegetables revealed significant genetic disappearance of the vegetables. Impact assessment of the project revealed a significant increase in farmers' income due to their involvement in the project and many showing interest to adopt some of the vegetables into their cropping system. The adoption experiences were similar due to cultural similarities in all the States, the emerging participatory on-station and on-farm extension approach proved to be very effective in under-utilized indigenous vegetable production. The approach engendered farmers' interest and sense of ownership which led to a registered Vegetable Farmers Association in some States.

Efficiency of *Bradyrhizobium japonicum* in different formulations and when co-inoculated with *Bacillus subtilis* on soybean in a Kenyan soil

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The major setback in successfully obtaining an effective inoculant is overcoming difficulties in formulating a viable and user-friendly final product as the live nature of the active ingredient underscores the importance of formulation in maintaining the microbial cells in a competent state. Co-cultures of rhizobia and PGPR (Plant Growth Promoting Rhizobacteria) are also known to influence the efficacy of the symbiotic bacteria on plant biological nitrogen fixation. A greenhouse experiment was set to assess the formulation effect of one strain i.e. *Bradyrhizobium japonicum* 532c (granules, liquid and broth) and to determine the efficiency of co-inoculation of *Bacillus subtilis* with two strains of *Bradyrhizobium japonicum* (532c and RCR 3407). The objectives were evaluated on 2 soybean (*Glycine max* L.) varieties: Nyala, a non-promiscuous variety and TGx1740-2F, a promiscuous test variety. A non-sterile soil from Central Kenya (Chuka) classified as a Nitisol was used. Nodule occupancy was determined by PCR-RFLP. Most of the inoculants showed increased nodulation and biomass yields as compared to the un-inoculated controls with a higher response seen in the promiscuous TGx1740-2F variety as compared to the non-promiscuous variety. The liquid and granule-based inoculants had higher biomass yields suggesting an impact of formulation on the effectiveness of the inoculants. The co-inoculants also gave higher yields but showed no significant differences to the rhizobial inoculants alone. Nodule occupancy was 100% for all the rhizobial inoculants as well as the co-inoculants emphasizing the infectivity and high competitiveness of 532c and RCR 3407 strains even in the presence of indigenous strains (80-113 cell/g of soil). These inoculants, though not initially made for SSA countries, showed promising increased yields in a Kenyan soil containing significant populations of native rhizobia nodulating soybean, signifying a possibility of their adoption in increasing soil fertility and crop yields in the poor SSA soils.

Relationship between phosphorus status and nitrogen fixation by common bean under drip irrigation

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The current study aims to examine the response of contrasted recombinant inbred Lines (RILs) of common bean to the application of phosphorus (P), to identify the bean RILs which were efficient in P utilization when dependent on N2 fixation as a source of nitrogen. The experiment was conducted at the experimental farm of Agricultural Research Station of the Nubaria District, Behera, Egypt during the winter seasons 2008-2009. Three levels of mineral phosphorus (P) fertilizers were applied (0, 45 and 90 kg P2O5 ha^{-1}). Nodulation, plant growth parameters, leaf area, soil Olsen P, pH, and phosphorus and nitrogen of shoots, nodules and seeds were measured. The results have shown that the RILs responded positively to P application levels. The best values were observed in RILs 75, 83 and 34. Vegetative growth parameters were significantly enhanced by increasing levels of phosphorus. The highest level of P (90 kg ha^{-1} P_2O_5) gave the optimal values of growth parameters for all common bean RILs while control plants obtained the lowest values. An increase of Olsen P and a decrease of soil pH were also observed with increases in phosphorus. These results led to the conclusion that phosphorus applied to Nubaria soil i) improved the soil fertility, ii) enhanced the ability of root nodules of common bean RILs to fix atmospheric nitrogen and iii) increased the release of H+ by roots, thus decreasing soil pH and reducing the immobilization of phosphorus in the soil solution and transforming it into available forms for the plant.

Experiences on the upscaling seed priming and microdosing of millet and sorghum in Mali

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Farming in pearl millet and sorghum producing areas in West Africa is very risky due to variability in rainfall, pest attack, highly variable grain prices and limited access to input. These may be the major reasons why the uptake of new technologies has been slow in these areas. A project was initiated by the Dryland Coordination Group in Norway and Institute d'Economie Rural in Mali to develop low cost and low risk technologies for these areas. The emphasis was on combining seed priming and microdosing. Seed priming is a technology that consists of soaking seeds for 8 hours in water before sowing and microdosing consists of applying 0.3 g fertilizer (NPK 16-16-16) per planting pocket corresponding to about 3 kg fertilizer/ha. Field trails in the Mopti region of Mali showed that millet doubled when combing these two methods. These methods were introduced in collaboration with local NGOs in the period from 2007 to 2009 in the regions of Koulikori, Segou and Mopti. A survey was undertaken in 2011 among 120 farmers to access the uptake of the technologies two years after the completion of the project. The results showed that 68% percent of the farmers in the project areas had adopted microdosing while 51 % had adopted seed priming. The survey results showed that adoption of seed priming and microdosing was higher in small sized farms as compared to large farms. The land size used for the new technologies differed between the regions. In the Mopti and Koulikoro project areas, 42% of the land was under microdosing while seed priming was used on 48 % of the land. In the Segou region, only 6% of the land was under seed priming and microdosing. One reason that can explain the differences in the uptake of microdosing was distance to the nearest outlet for mineral fertilizer outlet was 53, 22 and 5 km respectively for Segou, Mopti and Koulikoro regions. There was a local demand to purchase of mineral fertilizer and in many villages local outlets for fertilizer have been established. Numbers of food insecure months in the regions that have adopted the technologies have been reduced from 4 months to 1 month. The reasons why the technologies have been adopted are the low labour demand and the low cost of the technologies. Uptake of these technologies does not require any fundamental change in the farming system. One addition benefit of these technologies is also increased access to fodder as when yield increases the straw yield will also increase. Increased straw yield is also important in order to recycle more organic materials to the soil. These technologies can therefore be considered as the first step in the development of more high productive and sustainable farming systems in the drylands areas of West Africa.

Impact of adopting improved rice varieties on farmers' gross margin in Nigeria

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Gross margin is usually used as a measure of profitability of an enterprise. This study assessed the impact of improved rice varieties adoption on rice farmer's gross margin in Nigeria based on cross-sectional data of 563 rice farmers selected from three states, representing the three major rice producing ecologies. The study adopted the Local Average Treatment Effect (LATE) estimation techniques to provide a consistent estimate of the impact of Improved Rice Varieties (IRV) adoption on gross margin from rice production. The study revealed an observed increase of 12% in output for all the respondents. Farmers that adopted IRV had about 11.5% and 16.6 % increase in rice output and income respectively. Gross margin of adopter was 20.5% greater that of the non-adopters. The result of the LATE estimate showed an impact of N 2500.50 on gross margin from rice production. However, the impact on gross margin was higher among the male headed households (N 26435.00) than the female headed households (N 1256.89). Adoption of IRV also had a higher impact on the poor farming households (N4535.20) than the non-poor (N2790.35) this implies that it was pro-poor in nature. Therefore, adoption of IRV can lead to sustainable increase in productivity, makes rice farming profitable and can be a way out of poverty. This study recommends that more awareness should be created through the education of farmers on the need to continue adopting IRV for increase in output. The existing seed subsidy should be well implemented and properly monitored to encourage adoption of IRV.

Use of arbuscular mycorrhiza and different sources of phosphorus in domestication of the jujube tree

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Zizyphus mauritiana Lam., often called Indian jujube or ber, is a multipurpose fruit tree that provides high quality products: fruits, medicines, fodder and fuel. Interest and attention are being focused on fruits of jujubes that assume food security, health, and provide a source of income for the people of the rural areas in Sahelian and Sudanian zones in West Africa. However, jujube fruit trees are slow growing and little is known about their cultivation. Domestication of this tree crop could be achieved through a combination of approaches that could include the selection of different provenances based on product characteristics, vegetative propagation of selected trees, training and pruning, application of rock phosphate (RP) and others phosphorus fertilizers in P-deficient soils and arbuscular mycorrhizal (AM) inoculation. Responses of jujube fruit seedlings to AM inoculation and fertilization with RP from West Africa were examined in the present study. Mycorrhizal dependence (MD) of the jujube seedlings and of twelve other forest fruit species was assessed with five species of AM fungi, *Acaulospora spinosa* Walker and Trappe, *Glomus mosseae* (Nicol. and Gerd.) Gerd. and Trappe, *G. intraradices* Schenck and Smith, *G. aggregatum* Schenck and Smith emend. Koske and *G. manihotis* Howeler, Sieverding and Schenck. *Z. mauritiana* seedlings showed the highest MD values, reaching a maximum of 78% with *G. aggregatum*. The jujubes seedlings grew poorly without mycorrhizal colonization and without RP applications. However, AM jujubes with RP applications achieved better results in terms of height,

biomass and absorption of nutrients. AM jujube seedlings mobilize more efficiently P from soil and Tilemsi (Mali) RP than those from Taïba (Senegal) and Kodjari (Burkina Faso) RP.

Effets d'une bactérie solubilisant le phosphate naturel et des champignons mycorhiziens sur la colonisation des racines et la croissance du blé

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L'effet de *Pseudomonas* sp. BR2, isolé de la rhizosphère du blé irrigué du Mali, sur la répartition des microorganismes rhizosphériques solubilisant le phosphore, la colonisation des racines du blé par les mycorhizes indigènes et introduites dans les sols agricoles et la croissance du blé, a été vérifié dans un essai sol plante. Les plantes de blé ont été cultivées pendant 4 semaines dans un sol pauvre en P provenant du Mali et fertilisées avec du phosphate naturel de Tilemsi. Les traitements d'inoculation incluent la bactérie Pseudomonas sp. BR2 et le champignon mycorhizien Glomus intraradices. En fonction du type de sol (stérilisé ou non), le taux d'inoculation des graines affecte différemment la colonisation des racines du blé par la bactérie, mais aucune différence significative n'a été observée entre les types de sol. L'inoculation avec Pseudomonas sp. BR2 en absence de fertilisation phosphatée, n'a eu aucun effet sur la population microbienne totale, mais a fortement augmenté le nombre de microorganismes rhizosphériques solubilisant le P. Co-inoculé avec G. intraradices, Pseudomonas sp. BR2 a significativement réduit la taille de la population bactérienne solubilisant le P, et a, en même temps, provoqué une hausse des champignons solubilisant le phosphore. Après application de la roche phosphatée, Pseudomonas sp. a significativement augmenté la taille des microbiennes solubilisant le P avec un maximum d'efficacité en présence de G. intraradices. Le taux de mycorhization des racines et le pourcentage de mycorhizes viables ont été significativement stimulés par la présence de Pseudomonas sp. en présence du phosphate naturel de Tilemsi. En plus de la solubilisation du P, la rhizosbactérie Pseudomonas sp. a stimulée la croissance du blé en favorisant l'établissement des mycorhizes et des MSP dans la rhizosphère.

Promouvoir les agricultures fragiles par la gestion intégrée des eaux et sols dans les agrosystèmes du nord Bénin

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Le développement agricole du Bénin, à l'instar des autres pays de l'Afrique subsaharienne, est sérieusement menacé par la dégradation et la baisse de la fertilité des sols. La plupart des systèmes de cultures utilisés aboutissent à brève échéance à la dégradation des sols. Ceci se traduit par une baisse des réserves en matière organique par érosion et sur-minéralisation. Une dégradation de la structure physique du sol accompagne généralement cette perte de matière organique, accroissant ainsi le danger d'érosion des terres. Pour trouver des réponses à ce problème de baisse de fertilité dans les zones déshéritées comme les départements de l'Atacora et de la Donga, il a été initié un projet intitulé Integrated Nutrient and Water Management for sustainable food production in the sahel. Des traitements micro-dose et fertilisation recommandée sous diverses techniques de conservation des eaux et des sols (billons cloisonnés, cordons pierreux, nids d'abeille, labours en courbe de niveau, billons simples perpendiculaires, labour à plat)nt été comparés. Les démonstrations ont été conduites dans les communes Ouaké et Boukoumbé. Trois villages ont été sélectionnés à Boukoumbé (Koumagou B, Koudogou, Koukoua) et trois villages à Ouaké (Allayomdè, Tchallade et Kalla). 20 paysans par village ont été suivis. La collecte des données est essentiellement basée sur la mesure des paramètres de productivité. La mesure des paramètres de productivités et la récolte sont faites par le paysan, en présence du technicien qui s'est chargé d'appréhender l'appréciation paysanne des technologies proposées sur la base de critères de choix. Il n'y a pas de différence significative entre lesrendementsen graindes différents niveaux de fertilisation. Autrement dit, la microdose et la fertilisation recommandée donnent des rendements en grainsimilaires. Les rendements en grains sont les mêmes dans les trois villages de cette commune. Lorsque nous prenons les différentes techniques de conservation des eaux et des sols, on constate que ces techniques ont significativement les mêmes effets, sur le rendement en grain.En somme la microdose permet de réduire les coûts de production et d'avoir des rendements quasiment identiques à la dose recommandée. Il s'agira pour le futur d'orienter les producteurs en plus des techniques de gestion de l'eau, d'opter pour la microdose sur le maïs.

Contributions of N2-fixing legumes to soil fertility improvement: opportunities for integrated management of soil fertility

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The low yields and productivity of agricultural cropping systems in sub-Saharan Africa is due to the original poverty of soils and low application of external inputs. The use of chemical fertilizers is particularly limited by the lack of financial resources, inefficient distribution systems, poor agricultural production and marketing-supporting policies and other socio-economic factors. The traditional long-term fallow system (10-15 years of fallow, followed by 3 to 5 years cropping) of small farmers is no longer practical because of the high increase of population pressure leading high demand for lands. Thus, the maintenance of soil fertility for a sustainable agriculture in smallholder farmer's fields remains a challenge for agricultural research. Some work on short-term fallow systems have been undertaken as alternatives for the traditional long-term fallow system. The contributions of N2-fixing legumes crops through biological nitrogen fixation (BNF) to N balance have been investigated. Alternative, cost-

effective and socio-economic viable means of improving and maintaining soil fertility using N2-fixing legume crops as source of N and the improvement of nutrient use efficiency from small quantities of fertilizers usually applied by farmers were also investigated as options to improve soil fertility. Legume crops could also improve P availability of some cheaper local agro-mineral resources such as rock phosphates. This paper reviews the main research achievements with a special focus on different opportunities for a sustainable management of soil fertility for a better use of N2-fixing legume to improve the performance of traditional low input systems.

Évaluation des variétés de soja et leurs introduction dans le Sud-Kivu pour lutter contre la malnutrition et l'infertilité du sol

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La culture de soja procure aussi la fertilité au sol en facilitant la fixation de l'azote atmosphérique et en profitant de sa biomasse enfouie et utilisée comme engrais vert les fanes de cette dernière permettant de restituer l'azote au sol. Les recherches dans d'autres pays comme le Rwanda, le Nigéria, le Malawi et le Kenya où ces variétés de soja sont utilisées, ont donné des résultats favorables en se basant surtout sur le rendement à l'hectare. Pour la RDCongo et en particulier dans le sud-Kivu en territoire de Walungu et Kabare, avec l'approche participative, nous avons pu identifier les variétés adaptées aux différents milieux paysans et ces dernières seront en multiplication par les agriculteurs membres des associations pour les prochaines saisons culturales. L'évaluation de 15 variétés de soja a été menée pendant une saison culturale (saison A2012) avec la participation de membres des associations et agronome qui ont installé et géré les essais sur le rendement potentiel de différentes variétés de soja dans le milieu paysan en raison de deux essais par site. Parmi ces 15 variétés, la variété locale :Impérial et les variétés en provenance du Kenya: Saga, Squire, S823/6/16, Sequal ont été appréciées par les agriculteurs membres des associations qui vont passer à leurs multiplications tout en utilisant les engrais et l'inoculum pour ainsi avoir une grande quantité de semence pour une large dissémination. La prochaine étude devra se baser sur l'utilisation de ces semences de soja par les paysans en vu de garantir aux ménages des conditions meilleures de santé par une bonne nutrition à travers les valeurs ajoutées affectées à cette culture les outils de transformation seront donc d'une importance très capitale pour une bonne promotion de cette culture et l'amélioration de conditions de vie des ménages.

Exploring options for use of indigenous and improved legume green manures for improving maize yields in Western Tanzania

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Maize is an important staple food in Tabora Region of Western Tanzania whose population is above 2 million people. Land degradation in this flue–cured tobacco producing region is widespread as a result of deforestation and frequent use of uncontrolled bush fires. The bulk of maize grain is produced in smallholder farms under rain fed conditions. Maize grain yields are generally low due to low soil fertility and low levels of inorganic fertilizer access and use. The problem of food insecurity among smallholder farmers is exacerbated on sandy granite derived soils whose inherent fertility is too low to support optimum maize plant growth. Sandy soils are deficient in organic matter and the major plant soil nutrients N, P and S. The low organic matter content of the sandy soils leads to poor nitrogen use efficiency. A farmer participatory field study was established at Tumbi Agricultural Research Institute located S 05004'01.5'' E 032040'09.3 on a low fertility sandy textured Ferralic Acrisol. The objective was to explore options of using green manures from indigenous legumes (*Chamaecrista rotundifolia* (Pers) Greene and *Indigofera astragalina* DC) and the improved legumes (*Canavalia brasiliensis* Mart.ex Benth. and *Grilicidia sepium* (Jacq.) Kunth ex Walp on maize yield improvement. The trial was carried out with farmers' participation as a field school. The treatments were (i) Absolute control (ii) *G. sepium* (iii) *C. brasiliensis* (iv) *C. rotundifolia* (v) *I. sangalina* (vi) NPK (23:10:5) 100kg/ha. Green manure application rate was 10 tons/ha. Forty days after sowing maize var STUKA, 50 kg/ha NPK was topdressed. The experiment was a randomized complete block design with three replications. Results show that green manure application resulted in significant (P=0.05) maize grain yield compared to the control treatment. Supplementation of maize with half the rate 50 kg/ha NPK resulted into higher maize grain yield compared to the 100 kg/ha NPK treatment. This demonstrated better fertilizer use efficiency when green manure was applied into the soil. Farmers' assessment of green manure sources was based on labour cost and the sustainability of biomass production. The choice of farmers show that *Chamaecrista rotundifolia* > *Canavalia brasiliensis* > *Gliricidia sepium* > *Indigofera sangalina*. *G. sepium* and *C. brasiliensis* are perennials, while *Chamaecrista rotundifolia* dies during the dry season with subsequent regrowth during the on-set of rainfall. *Indigofera astragalina* is an early growing herb. The results of this study demonstrate the potential of indigenous legumes and the imperative need of organic matter use as a pre-requite factor for improving the productivity of degraded sandy textured soils.

Canavalia brasiliensis brings a new horizon in agriculture in semi-arid Tanzania

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Agroforestry (AF) research at Tumbi Agricultural Research Institute has concentrated on the testing different nitrogen-fixing legume species with farmers in an attempt to improve soil fertility in the flue tobacco-cereal based farming system in the semi-

arid Tabora Region of Western Tanzania. Flue tobacco production is associated with deforestation of Miombo woodland with the purpose of collecting wood for drying tobacco leaves and a search of fertile nematode-free soils. Low soil fertility is a major ecological limitation to increase of biomass for human and livestock sustainability. Legume based improved fallow systems of *Sesbania sesban*, *Gliricidia sepium*, *Tephrosia vogelii*, and *Cajanus cajan* were tested for one or two years in rotation with maize. The improved fallow system showed positive maize grain increments but it has not been widely adopted because of socio-economic limitations. Some of the limitations include, lack of multiple products to farmers, increase of household labour demand, low biomass production, induced soil moisture stresses, crop pests, and low animal interactions. Household labour availability is a critical socio-economic factor in flue tobacco producing households. *S. sesban* improved fallows were found to increase soil nematodes an environmental sensitive problem to tobacco growing. *C. cajan* was accepted by farmers for production of marketable fresh fruits it has low production of biomass. Additionally, the technology of rotating *Acacia crassicarpa*, *A. julifer*a, *A. leptocarpa*, *Leucaena pallida* or *Senna siamea* and crops was also tested with farmers with the purpose of improving soil fertility and provision of the much needed wood for drying tobacco leaves. *Acacia* spp., grew faster enough to provide the much needed wood but it has been found that these trees negatively affect local hydrology that most of local water wells have dried up in the study areas. The introduction of *Canavalia brasiliens* as an alternative candidate for improving soil fertility has proved to open a new horizon for improving nitrogen input in the soil. *C. brasiliensis* is adapted to low fertile soils and semi-arid conditions because of its deep rooting system that it is able to survive a 5-7 month dry period typical of Tabora region with the production of fresh biomass between 35-50 tons/ha. Canavalia brasiliensis is easy to establish, suppresses weeds and does not need high labour demand for establishment like the previous introduced legumes. It provides important N for livestock during the dry season, by harvesting, air drying of leaves and mixing with low quality crop residues. Growing *C. brasiliensis* has an addition advantage of attracting bees for honey, an important product of the Miombo woodland ecosystem.

Mycorhiza may be a better component of ISFM practice in highly weathered soils

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Declining soil productivity is the challenge for food security in Africa and especially in Walungu district of DR Congo. One of the constraints is Phosphorus which is the critical element in nitrogen-fixing process, crop productivity and availability of them is a serious problem in Walungu weathered soil. One opportunity is to valorize mycorhiza action by integration a better ISFM practices such us organic matter and fertilizer management. For those, the trial was conducted in Walungu weathered soil to test effectiveness of *Glomus intraradices* to improve P availability and uptake of cassava, banana and soybean. TSP has been applied for some treatments. Organic matter was combined with AMF for improve P uptake in soil. Soybean was inoculated with rhizobia to increase nitrogen-fixation. The following parameters were evaluated: root development, P uptake, and yield and nodulation development to soybean. The result show that AMF reduced root growth in cassava, banana and soybean systems respectively by 37, 36.5 and 39.8% but increased phosphorus absorption 26, 21 and 32% in cassava, banana and soybean. The results showed that application of AMF increased the rate of phosphorus release by 34% and 27.2% in soil in cassava and banana systems. The yield was highest in soybean when the AMF was combined with organic matter and yield increased by 36% when OM was applied. In point of view of local strains, some best opportunity has been shown to phosphorus absorption but efficiency was not higher. This has opened a way for new research on mycorhiza as a component of ISFM practice. Investment in soil microorganisms offers good opportunities for production in weathered soils but application of organic matter improves microbial activity.

Nitrogen fixation increases in South-Kivu by applying rhizobium to legumes

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Inoculation with rhizobium is one of the better opportunities for increasing nitrogen fixation in South–Kivu and its deficient and degrading soils. But some conditions are required for optimize inoculant effect such us optimized phosphorus application, acidity management, micronutrient supply, starter nitrogen and organic input management. Unless soil conditions are sufficient, legumes have low potential for nitrogen fixation. All of these factors have been examinated in South-Kivu agroecoystems by multi-participatory trials and constitute a major constraint of legume production and response to inoculums. For soybean, 10 varieties and for bean, 15 varieties have been introduced. Two varieties for each species were selected for their promiscouscity or specificity on nodulation. SB24 and PK06 for soybean and AND10 and CODMLB001 for bean. TSP was applied as a source of P. Five sites received trials in 3 seasons. The result shows the increase of soya yield at 84% from applied rhizobial inoculant. The middle has an impact on legume response to rhizobia. SB24 was more promiscuous than other varieties and has better response to rhizobia. The results of various tests show the interactions between environment, inoculant and phosphorus. In areas with better soil fertility, the response to rhizobium for specific and promiscuous varieties was high and increased yield ranging from 14 to 75%. The response to inoculant in area with low soil fertility was weak, ranging from -23% to 11% and shows little response to rhizobia. The addition of phosphorus increased yield from 18 to 68%. Soya bean has also responded to rhizobium more than beans in almost all sites. In soil where nitrogen was deficient, we observed low response to inoculant. The responses to rhizobia deserve special attention in the humid tropics because of heterogeneity of soils. In the future we eill examine micronutrients in order to achieve fuller impact from inoculant in South-Kivu.

The effect of no-tillage practice on soil fertility in Tunisia

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Since 1999, no-tillage (NT) has been introduced in Tunisia in order to achieve more sustainable agricultural systems. NT provides direct benefits to environmental issues of global importance, including control and mitigation of land degradation, mitigation of climate change, improved air quality and enhanced soil biodiversity. No-tillage areas increased from 52 ha in 1999 to 12000 ha in 2010. The aim of this work is to study the effect of this practice on soil fertility under Tunisian conditions. Soil samples were collected at 10 cm of depth from 6 farmers in northern Tunisia. Conventional tillage (CT), no-tillage during less than 5 years (NT<5 years) and no-tillage during more than 5 years (NT>5 years) have been practiced in each farmer's field experiments. Soil mineralization is followed under laboratory conditions at 28°C during 87 days. Carbon mineralization data are simulated using two-pool first-order kinetic equation. SOC content was significantly greater under NT than in CT (+0.3% and +0.7% in plots NT<5 years and NT>5 years, respectively. The SOC stored was approximately 1 t C $ha^{-1}y^{-1}$. This increase of SOC under NT compared to CT could be due to the restitution of crop residues which is more important in NT than CT. However, the evolution of soil carbon is determined by the balance between the input of organic matter and the output of CO_2 and tillage could influence this balance. In fact, NT practice increased soil mineralization under laboratory conditions about 30% and 70% for NT<5 years and NT>5 years respectively compared to CT. This result shows the importance of NT to enhance soil biological activity. Besides the effect of NT on soil fertility, an environmental effect was observed using simulation of mineralization kinetics. NT practice enhances stabilization of soil carbon compared to CT in order to reduce CO_2 emission, an important greenhouse gas.

Matching the need for biological nitrogen fixing grain legumes with most appropriate varieties in East and Central Africa

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The ability of grain legumes to provide a mechanism for the recycling of nitrogen from atmosphere to available forms into the biosphere makes them a key entry point for sustainable intensification of African smallholder agricultural systems. However, available genetic materials of different types of grain legumes show wide variability in term of ability to form symbiosis with rhizobial strains, adaptation to climatic and soil conditions, resistance/tolerance to biotic factors, responses to various agronomic management and preference by farmers, calling for a need to target germplasm(s) to specific environment within the farming system. We used a system approach whereby the improved local and introduced varieties of bean (climbers and bush type) and soybean were screened for their response to inoculation with rhizobial strains and for adaptation to biophysical conditions in the highlands of eastern Democratic Republic of Congo, Western Kenya and Rwanda. We have observed that varieties which show high BNF potential do not necessarily fit well in the cropping systems or have the desired characteristics by farmers. The process of selecting legumes with high BNF potential need to be an interactive one, in which the researchers works closely with farmers at all stages, responding to the farmers' needs and those of the cropping systems. There exists no "wonder legume grain variety to solve all problems in all cropping systems, but there does exists a rich and varied germplasm pool of grain legumes, which allows one to match specific needs for BNF on a farm with the most appropriate variety or a mix of varieties adapted to farmers' agro-ecological and socio-economic conditions.

Response of *Acacia senegal* provenances to inoculation with selected rhizobial strains in relation to soil origin

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We numerated the background of root nodulating bacteria in soils. The focus of the study was to underline theresponse of three *Acacia senegal* provenances to inoculation with selected rhizobial strains under greenhouse condition in two non-sterilized soils from arid and semi-arid zones of Senegal to highlight the correlation between inoculation, plant nodulation and growth parameters, and soil origin. We investigated the background of rhizobial in soils by most probable number (MPN) method in growth chamber with three Senegalese *A. senegal* provenances (Dahra, Ngane, Kidira). A greenhouse experiment was performed to evaluate the effect of 11 rhizobial strains on nodulation and growth of three *A. senegal* provenances (Dahra, Senegal; Tera, Niger and Makueni, Kenya) grown in two contrasted soils, Darha and Goudiry. The most probable number (MPN) of bacteria was lower in Dahra soil than Goudiry soil, in all A. senegal provenances. Our results indicated that the effect of inoculation on nodulation and growth (shoot, root, nodule and total dry matter, and height) of A. senegal seedlings varied with rhizobial strain, provenance and soil origin. There was a significant ($P<0.05$) inoculation, provenance and rhizobial strain x provenance interaction for nodulation and plant growth parameters. Principal component analysis (PCA) indicates that rhizobial inoculation variability affected nodulation and growth parameters of *A. senegal* provenances. Nodulation was positively correlated to seedlings shoot dry weight and height in both soils. Soil type significantly ($P<0.05$) affected inoculation and provenance effect was most clear in soil from Dahra. The response of *A. senegal* plants to inoculation is dependent to rhizobial strain, plant

provenance and soil origin. The nodulation of plants is mainly dependent on the amount of nitrogen in soil than the number of specific rhizobia in soil. Our results suggested that inoculation is an appropriate way for improving nodulation and growth of *A. senegal* seedlings. However, it is more advantageous to match effective strains with specific provenances and environmental conditions.

Enhancing biological nitrogen fixation in smallholder farms through rhizobial inoculation in the Nigerian Guinea Savanna

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The ability by legumes to fix atmospheric nitrogen makes them excellent components within various farming systems because they provide residual nitrogen and reduce the needs for mineral nitrogen fertilizers by associated non-legumes. In Nigeria, the most widely cultivated legumes are cowpea (*Vigna unguiculata*), groundnut (*Arachis hypogaea*) and soybean (*Glycine max*). Despite their status as major income earners, yields of these grain legumes are very low relative to their potential. Inoculation using elite rhizobial strains is one of the strategies employed to enhance N2-fixation and, hence yield, in legumes. This paper highlights the results of two years of inoculation activities in Nigeria. In spite of their alleged promiscuity, the TGx soybean varieties exhibit high frequency of response to inoculation with average yield increases due to inoculation being about 30% and a range of 6-70% depending on planting date, soybean variety and agro-ecology. Response to inoculation generally appears to be higher in the Sudan savanna than in the Northern and Southern Guinea savanna agroecologies. The results also show a general tendency for the soils of the Southern and Northern Guinea savannas to have relatively higher rhizobial populations than those of the Sudan savanna. Inoculation trials for cowpea have had mixed results compared to that of soybean. Field trials have generally shown poor response to inoculation although greenhouse studies using inoculant broth of strains USDA 3384 and USDA 3451 exhibited yield increases in dry matter in 26 out of 30 soils.

Reactivation of fungal propagules in disturbed and degraded soils by pioneer plant species: Improving soil chemical and microbial quality

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Change on the structure of mycorrhizal fungi community related to the modification the composition of the aboveground vegetation is well known. Soil content of mycorrhizal propagules depends on the mycorrhizal status and dependency of plants that influence also the physico-chemical and biological soil properties. Studies conducted within the degraded sclerophyllous forest of *Uapaca bojeri*, Arivonimamo Madagascar, showed that the most dominant pioneer shrub species, *Leptolaena bojeriana*, which is associated with both endomycorrhizal and ectomycorrhizal fungi, enhanced soil microbiological and chemical properties, stimulated the fungal propagules and created fertile "islands". Soils previously influenced by the pioneer shrub species were significantly rich in total organic matter, total phosphorus and total nitrogen which were respectively 5.11 %, 3.63 mg kg^{-1}, 0.26 %, compared to the native tree, *U. bojeri*, soil that contained 4.26 %, 2.85 mg kg^{-1}, 0.19 % and the bare soil which contained respectively 1.76% of total organic matter, 1.45 mg kg^{-1} of total P and 0.09 % of total N. It was also recorded that soil enzymatic activities, global microbial activity were significantly high on *Leptolaena bojeriana* soil. Acid and alkaline phosphatase activity and global microbial activity were respectively 761.33 µg of p-nitrophenol h^{-1} g^{-1} of soil and 514.75 µg of p-nitrophenol.h^{-1} g^{-1} of soil and 10.97 µg of fluorescein. h^{-1} g^{-1} of soil on *L. bojeriana* soil, 314.02 µg of p-nitrophenol h^{-1} g^{-1} of soil, 302.54 µg of p-nitrophenol h^{-1} g^{-1} of soil, 6.70 µg of fluorescein. h^{-1} g^{-1} of soil on *U. bojeri* soil and 130.56 µg of p-nitrophenol h^{-1} g^{-1} of soil, 166.51 µg of p-nitrophenol $h^{-1}g^{-1}$ of soil, 5.60 µg of fluorescein. h^{-1} g^{-1} of soil on bare soil. The most probable number of mycorrhizal propagules (MPN) was also significantly high with 457 MPN per 100 g of soil for *L. bojeriana* soil, 133 MPN per 100 g of soil for *U. bojeri* soil and 10 MPN per 100 g of soil for the bare soil. Thus, the establishment of the pioneer shrub species on degraded soil had net positive effects onsoil quality which can influence the development of late successional plant species by improving both nutrients availability and acquisition.

Agroforestry and soil health: Linking trees, soil biota, and ecosystem services

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Agroforestry has been increasingly recognized and practiced as a land management option that can simultaneously contribute to food security and the conservation of biodiversity and ecosystem services. Agricultural ecosystems both require and generate ecosystem services and may enhance or degrade natural capital through time depending on how they are managed. Soil health is a key indicator of the state of natural capital, and is considered here as an integrative property reflecting the capacity of soil to respond to agricultural management by maintaining both the agricultural production and the provision of other ecosystem services. Soil organisms contribute to a wide range of ecosystem services that are essential to the functioning of natural and managed ecosystems. Evidence has shown that there is a strong link between organisms above- and belowground, highlighting the impact that land use and management can have on the provision of soil based ecosystem services. This review first discusses the potential of trees to modify the soil and its impact on soil biota. The exploration of the linkages between the biological

activity of soil organisms in agroforestry systems and their impact on soil-based ecosystem services and soil health follows next. Then recent advances in soil health monitoring systems and approaches to harnessing the complementary nature of local and scientific knowledge are discussed. We conclude by highlighting the role of agroforestry practices in adaptive and multifunctional land management with a view to enhancing soil health and agricultural sustainability, as well as recommendations for future research.

Fostering south-south knowledge sharing for ISFM capacity building in agricultural landscapes of Southern Africa

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Agriculture can greatly benefit from integrative approaches that combine formal and informal knowledge to address current sustainability problems. The increasing attention paid to local knowledge in recent years results from the recognition that the knowledge of land managers (e.g. farmers) that have been closely interacting with their environment for a long time can offer many insights about the sustainable management of the soil resource. Increased concern about soil management as a key determinant of sustainability in agricultural landscapes has led to the identification of early warning indicators to monitor changes in soil quality, and their impact on crop productivity and other ecosystem services, as affected by land use change and agricultural intensification. The InPaC-S methodology, developed through South-South collaboration, includes a number of tools to guide the participatory integration of local and technical knowledge about soils and their management. Here we describe the methodological approach during its development in Brazil and more recently during its successful utilization in Mozambique for capacity building of IIAM researchers and their partners in national extension services, NGOs, local government with the financial support of the Africa-Brazil Agricultural Innovation Marketplace. This research is part of a continuing effort to strengthen local communities, environmental/agricultural institutions and governments with tools that support local decision-making in natural resource management and promote sustainable land use in agricultural landscapes.

Determinants of adoption of soil erosion control technologies in the Mt. Elgon highlands in Uganda

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The study was conducted in Mt. Elgon highlands, which account for 50% of the land degradation in Eastern Uganda. The study was specifically undertaken in Kween and Bukwo Districts, where highlands cover about 37% of the total land area. Farmers in this zone experience severe land degradation due to the steep rugged nature of the terrain and the problem is aggravated by heavy rains. The two major forms of land degradation in the zone are soil erosion and nutrient depletion. A multi-stage (six stages) sampling procedure involving a combination of purposeful and random sampling procedures was used to draw a sample of 240 farmers. Primary data was collected from farmers using a semi-structured questionnaire and through face-to-face interviews. The double-hurdle model was used to analyse the determinants of both incidence and intensity of adoption of soil erosion control technologies. This model assumes that farmers make two sequential decisions with regard to adopting soil erosion control technologies. Each hurdle is conditioned by the farmer's socio-economic characteristics and technology-specific attributes. In estimating the double-hurdle model, a probit regression (using all observations) is followed by a truncated regression on the non-zero observations. Overall incidence of adoption of soil erosion control technologies is appreciably high – almost all farmers have adopted at least one technology. Farmer's decision to adopt contours is positively and significantly affected by the diversity of farm tools that the farmer owns and the perception that soils are fertile. Unexpectedly, doing farming as the main economic activity is associated with low probability of using contours. Facilitating farmers to own different types of farm tools, reducing the distance to output markets and increasing the frequency of extension visits will increase adoption of Napier grass. Married farmers are less likely to adopt Napier grass. Adoption of trees will increase if farmers acquire more hectares of land. Tree planting is limited by long daily farming duration and location on the landscape – uphill and mid-hill. Increasing the frequency of extension visits to farmers, facilitating farmers to own different types of farm tools and increasing farmers' incomes will increase adoption of trenches. Men are less likely to adopt trenches and so are farmers with farmlands located at the middle section of the landscape. Male farmers and those with high income are more likely to make terraces on their farmlands. Uphill location is a serious limitation to adoption of terraces. Intensity of adoption of soil and water erosion control technologies is positively and significant affected by short distance to output market and possession of technical knowledge of how to apply the technologies.

Land-care bylaws increase adoption of soil erosion control technologies: evidence from Mt. Elgon highlands in Eastern Uganda

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Uganda is challenged with the task of increasing agricultural land productivity in its pursuit of agricultural-led economic growth. Among others, soil erosion control is important to realizing increased agricultural land productivity. While the National Agricultural Research System has generated technologies that can sustainably reduce soil erosion, most farmers have not adopted them. The low incidence of adoption has been partly attributed to lack of locally enacted bylaws, limited involvement of local communities in bylaws formulation and weak enforcement of penalties. Using a case study of Kween district this study identifies the land-care bylaws and uses descriptive statistics to determine the effect of bylaws and local community involvement in bylaws formulation on adoption of technologies stipulated in the bylaws. Results indicate that there was minimal involvement

of local communities in formulating of the land-care bylaws in Kween district. Generally, involvement in bylaws formulation was dominated by men and there is sufficient statistical evidence of a relationship between sex and involvement in bylaws formulation. Disregarding other factors, both bylaws and involvement of local communities in bylaws formulation increase adoption of technologies. Unfortunately, the penalties for breaking the bylaws are yet to be enforced partly due to inadequate capacity and empowerment of the Bylaws Implementation Committee (BLIC) to undertake their roles. Thus, there is need to train and empower the BLIC to enforce the penalties as a strategy of stimulating further technology adoption. Also, other districts facing the challenge of land degradation should emulate the example of Kween but ensure adequate involvement of both men and women in the bylaws formulation processes.

Use of rhizoobial inoculants on soybean in east DR Congo

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The increase of fertilizer use to improve agricultural production is a need for most developing countries. A local and sustainable source of fertilizers is needed especially for nitrogen that is the most important nutrient of plant. Nitrogen-fixing legumes provide the basis for developing sustainable farming systems that incorporate integrated nutrient management. At present, legumes such as soybean, common bean, groundnuts, chickpeas, cowpeas, etc., are fixing approximately 11 million tons of N in developing countries. The BNF has been tried in many countries globally and good results came out. This experience from other regions should be used as model in DR Congo. A study was carried out in the East of DR Congo for testing some new varieties of soybean with inoculation by rhizobia. A split plot design was used with the varieties as the main plot and inoculation as the sub-treatment. It aims to evaluate the most responsive variety in term of nodulation for efficient plant nutrition within an agroecological zone where P and K are not the constraints. The findings show that all inoculated and uninoculated plants produced nodules but with different characters. A high number for inoculated plants gave for some varieties >50 and 100 reddish and grayish nodules respectively. As for the efficient nodules, all the best plots where those with inoculation while among the inefficient (grayish) there is mixture every time of plots with and without inoculation.. The addition of rhizobia activates the efficiency of nitrogen fixation. The fresh weight of nodules from inoculated plots increased 148% compared to the control (4.21 g and 2.84 per plant for with and without rhizobia, respectively). The distribution of nodules on the root structure showed difference among the primary and secondary roots. BNF is a strong and reliable approach of ISFM that might increase productivity in small-scale farmer condition with lower income. However, there are still some practical and technical approaches to address to make it successful, especially its availability and the need for more skills by farmers.

Nitrogen mineralization after combined and separate addition of compost and fertilizer in on-farm experiments in the highlands of Ethiopia

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We have studied combined and separate additions of compost and fertilizer on Humic Andosols in the central highlands of Ethiopia for five years and found consistently higher yields for treatments that combine half-dose of fertilizer and half-dose of compost compared to full dose of compost or fertilizer alone. The objective of this study was to evaluate if differences in N mineralization over time can explain the synergy effect on crop yields by the combined application. The experiment compared four treatments: an on-farm made compost (C), fertilizer, i.e. DAP + urea (F), half compost and half fertilizer (CF), and no-input as a control (O) and was replicated across farm fields on three farms. In each field a randomized complete block design with three blocks was used. Mineralization of N was estimated by comparing available N content (NO3- and NH4 in 2M KCl extracts) that has been excluded from root uptake with soil that has been accessed by roots. A polyvinyl chloride (PVC) plastic tube was inserted into the soil in each experimental unit and left there until next sampling occasion. At the same time the top 20-cm of the soil was sampled with an augur both outside and inside the PVC which was inserted at the previous sampling. The sampling procedure was repeated every 30 days after sowing (DAS). Mineralized N (NMIN) was calculated as NMIN=NPVC-NSOIL for each sampling occasion Concentrations of NSOIL followed the order C > CF > F > O and were similar after 150 DAS in the NPVC. Although the NSOIL was higher than the control for all treatments initial immobilization or loss of N was found for C, CF and F treatments. The immobilization/loss was most pronounced for the F and CF treatment that did not show a positive balance for mineralization until 120 DAS. We hypothesize that part of the fertilizer N in the combined treatment is immobilized in the compost material and made available to the plants later on in the cropping season while some of the fertilizer N in the F treatment is lost through leaching during the first 120 DAS.

Bio-economic modelling for ex-ante assessment of of ISFM technologies in Rwanda

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Rapid population growth and stagnation of agricultural yields in Rwanda have caused a steady decline in food production per capita, a continuous expansion towards the use of marginal land, and a strong degradation of land. The challenge of achieving simultaneously food security, rural welfare, land protection and soil fertility regeneration in the face of its high population is overwhelming to Rwanda. Technical options for a sustainable land use can be available; the major concern is how to induce farmers to adopt these technologies. The objectives of this paper are to assess the potential impacts of the ISFM technologies on

income, food production and soil loss for four types of farm households, and to assess policies that could induce adoption of these technologies. Model results show that these alternative agricultural technologies will clearly enhance food production and income for all farm household types except the full- time farm household for which cash at the beginning of the season is too restricted to switch to the new technologies. The outcomes of the model also reveal that ISFM technologies will prevent soil loss and improve soil quality since soil loss and SOC do not entail negative economic consequences. Off-farm employment policy will have a high impact on adoption among households with small farms and less off-farm opportunities because it provides cash that is needed to adopt the new technologies. Subsidies on inputs will substantially improve adoption of alternative technologies among literate farm households. Overall, provision of credit and availability of off-farm activities have emerged as policies that are most likely to enhance adoption of the ISFM technologies in all the farm households.

Agricultural technology performance among farmers in Central Africa

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In the past decade, a number of interventions targeting new technologies for smallholder farmers have been initiated, adapted and promoted in many countries in Sub-Sahara Africa. The technologies have ranged from introduction of new resilient or high yielding varieties to crop management practices to innovations for market access and nutrition among others. The new technologies are expected to have benefits that would motivate farmers to adopt them or use them. CIALCA project has been at the forefront of generating and promoting agricultural production technologies in Central Africa over the last 6 years. This paper evaluates the promoted technologies under the CIALCA project from a holistic perspective of farmers in Central Africa. It provides an indication of the extent to which the farmers are satisfied with the new technologies as an indicator for the long term adoption/uptake of the technologies. The paper is based on the data that was collected in July/August 2011 from three countries of Rwanda, The DRC and Burundi using a sample of 913 farmers. Data was analyzed by ordinal regression routine. The performance was measured on a five point scale indicating the extent to which farmers were satisfied with the agricultural production technologies that were available to them. Results from the analysis indicate that there was a significant difference in the levels of satisfaction with the technologies among the farmers in the three countries and mandate areas. A number of factors were assessed to explain the differences in the performance of the technologies. The odds of being satisfied with agricultural technologies increased when households that had fewer household members. The odds of being satisfied were also higher in Rwanda, Burundi, south Kivu and Bas Congo relative to North Kivu province. Farmers that indicated that the technologies had little on impact on their livelihoods were also more likely to be dissatisfied relative to farmers that felt there was a positive impact from the technologies. The odds of being satisfied was lower where farmers had knowledge of CIALCA as an entity compared to those who had heard of CIALCA. In addition, the chance of being satisfied were higher where farmers marketed their outputs in groups. Finally, farmers participated in technology evaluations were also more likely to be satisfied relative to farmers that did not participate on the evaluations. The results provide key indicators that highlight potential adoption of technologies following promotion efforts. It provides an indication of where the technology promotion efforts should be emphasized to achieve higher levels of uptake of the technologies. Technologies that emphasize group approaches and direct technology evaluations are likely to elicit higher levels of satisfaction and thus consequently leading to higher uptakes.

Mycorrhiza alters competitive interactions of *Acacia* and *Boswellia* seedlings in drought pulsing

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Arbuscular mycorrhizal (AM) fungi can have a substantial effect on moisture and nutrient uptake and therefore influence plant competition in stressful environments where resource availability is controlled by rainfall. In a greenhouse study, we examined the influence of drought pulsing and AM colonization on the competitive relationships between seedlings of the acquisitive species *Acacia etbaica* and the conservative species *Boswellia papyrifera*. Both seedlings benefited from AM when grown alone, though the effect was stronger for *Boswellia* seedlings. AM affected the competitive performance of the two species. The conservative species was not affected by intraspecific competition, whereas the acquisitive species was strongly negatively affected by intraspecific competition. This effect was even stronger in the presence of AM. In interspecific competition, the acquisitive AM species outcompeted the conservative species. Water pulsing and the presence of AM fungi did not affect the outcome of interspecific competition, and the aggressivity index of *Acacia* remained unchanged. Water pulsing strongly negatively affected Acacia seedlings. Colonization decreased with water pulsing in *Acacia* seedlings but increased in *Boswellia* seedlings. The extent to which AM influenced plant competition in water pulsed environment depends on the nature of the root system of the species. This study shows that both water pulsing and AM can modify the balance between intraspecific and interspecific competition. AM and water pulsing can adjust plant interactions and determine the establishment and survival of seedlings.

Isolation and characterization of endomycorrhizal spores from the rhizosphere of groundnut

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The main groundnut production area is located in the irrigated agriculture zone of south-west of Tangier, a sandy coastal area bordering the Atlantic and extending between Assilah and Kenitra. Little work on the mycorrhiza of peanuts in sandy soils, poor in water and in nutrients has been done. Soils were sampled from Laaouamra to a depth of 0 to 20 cm and the isolation of spores of mycorrhizal fungi was performed. The counting of spores was carried out under a binocular microscope. It is clear from this study that the potential for natural mycorhization after peanut cultivation gives a density of 5834 spores per 100 g of soil. The enumeration of the spores of this soil allows identifying 6 morphotypes using color, size and structure of the wall of spores as a criterion for identification. The distribution of these morphotypes of spores by decreasing density is as follows: Black, brown, yellow-brown, yellow, yellow green and white spores. Among the spores observed, three main types were identified: *Acaulospora*, *Scutellospora* and *Glomus*.

The Lead Farmer approach: an effective way of agricultural technology dissemination?

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The Lead Farmer model appears to become an increasingly common agricultural extension approach in developing countries in Africa. Premised on the idea that many farmers can be reached without straining extension officers and project staff, the Lead Farmer approach is, arguably, a response to donor demands for impact at scale in absence of a well-resourced national extension service. Typically, the Lead Farmer approach works with groups of 15 to 30 smallholder farmers, with knowledge and skills, feedback from farmers, and sometimes input provision all being channelled through the group's leader. The Lead Farmer is the main contact for the project and partner organisations. The centrality of one individual in this dissemination approach, raises questions regarding their selection as leaders, bias and selection in the pass-on of information to and fro farmers, power distributions and dynamics within the groups, their durability, etc. In addition, it raises questions regarding the Lead Farmer as appropriate entry point for input distribution, collective marketing and other types of agricultural interventions. This paper explores the implementation of the Lead Farmer approach within the N2Africa project in Zimbabwe, a project that aims to disseminate legume technologies to small-scale African farmers to achieve goals of improving soil fertility, farmers' livelihoods and food security in eight countries in Sub-Saharan Africa.We analyse the effectiveness of this approach in the dissemination of legume technologies and conclude that this depends as much on the Lead Farmer as it does on the group. From case studies, it will be illustrated that characteristics as education and commitment of a Lead Farmer matter, as does for example collaboration of group members in other activities. While confirming the drawbacks of the approach, we also illustrate how increased sustainability of capacity building can be achieved and as such, the chance of successful interventions and enduring impact.

Changing use patterns of natural resources supporting livelihoods of smallholder farming communities and implications on climate change adaptation in Zimbabwe

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Increased rainfall variability and extreme weather events in sub-Saharan Africa (SSA), present new challenges in rain-fed crop production and natural resources upon which livelihoods of smallholder farmers depend. Farmer participatory research approaches and Geographic Information Systems (GIS) were used over two years (2011-2012) to characterise and quantify the contribution of common natural resource pools in two smallholder communities of Wedza district, eastern Zimbabwe, in the wake of climate change and variability. Results indicated that major natural resources extracted from wetlands included water for domestic use, wild vegetables (e.g. *Senecio erubescens*); fish (e.g. *Sargochromis codringtoni*), wild tubers (e.g. *Coleus esculentus*), and wild fruits (e.g. *Eugenia malangensis* and *Syzgium cordatum*). *Miscandithidium sorghum* and *Phragmites mauritianus* where extracted for household income particularly by resource constrained households. For example, resource constrained households sold an average of 41 kg of *P. mauritianus* per household as mats and baskets, and obtained about US $68 per household within a period of two months. Firewood, wild fruits (e.g. *Vitex payox*, *Uapaca kirkiana* and *Parinari curatellifolia*) and small wild animals (e.g. *Lepus capensis* and *Cavia porcellus*) were obtained from woodlands. Resource endowed household harvested larger quantities of firewood, ~375kg per household per month, than the other resource groups, ~ 285kg per household per month. Whilst the resource constrained households consumed greater quantities of wild fruits, ~29 kg Uapaca kirkiana per household per month, 15 kg *V. payo*x per household per month) than other resource groups, ~ 21 kg Uapaca kirkiana per household per month, 7 kg *V. payox* per household per month. The differential access to natural resources by the different categories of households was influenced by recurrent crop failures due to increased intensities of agronomic droughts. Therefore, despite their projected decline, increased reliance on natural resource pools in the wake of climate change and variability in agro-ecosystems suggest lack of other alternative adaptation options. Sustainable use and management of common natural resource pools is vital in order to reduce pressure from emerging challenges of a changing climate and existing land use changes.

Conservation Agriculture based on direct drilling offers opportunity in Tunisia

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The Tunisian climate is Mediterranean, characterized by irregular, sudden, intense and relatively low rain-fall. Land degradation is continuing, water resources are becoming scare, and energy cost of farm products is continuously growing. Consequently, cereal producers can hardly make an economic return, while practicing conventional agriculture based on conventional drilling (CD) offers promise. Conservation agriculture based on direct drilling (CA/DD) gives farmers a chance to protect soils and rebuilt their fertility for an efficient use of any available form of water (rain-fall, irrigation). Such desirable efficiency does not come only by the use of the appropriate crop species, but necessarily by reducing water evaporation. To do so, a permanent mulching on the soil surface is the pivot of CA/DD. Since rain-fall fluctuates from one year to another, crop sequences should parallel with such conditions. Some couloirs have early rains (September-October) and late rains (May-June) too. In Bou-Salem (Governorate of Gendouba), early and late rains accounted for 26.2 % and 19.9 % of the 07/08 total rain for cereal growing season (September/07-June/08), respectively. These rains are not well capitalized in cereal production, when applying conventional agriculture. So, coupling the site specific approach and agronomy of opportunity is imperative to lift up farm productivity. The climate (rain, heat) of production sites should be characterized to better define growing seasons and make the appropriate agronomic sequence. Then, the agronomy of opportunity (producing the maximum of biomass whenever the climate and the biology of the desired crop are favorable) could be applied in different scenarios, under rain-fed and/or irrigation conditions. There is no static scheme to crop the land, and it is rather a dynamic management of soil, crops, and water. A particular emphasis should be put on use of strictly seasonal (fall, winter, spring, summer) cereals and legumes in order to make a continuing cropping with two-three crops a year. A potential scenario could be a fall- barley/springpeas/ summer short season-sorghum hybrid. Some crops including barley (*Hordeum vulgare*), oat (*Avena sativa*), sorghum (*Sorghum bicolor*), millet (*Pennisetum glaucum*), Lucerne (*Medicago sativa*) are used as cover crops and others still are under experimentation. So, AC/DD is a new ag-technology using the same species cropped in conventional agriculture but sometimes for a very different purpose. Some agronomic scenarios were successfully conducted. Sorghum was grown after a feed cereal (oat), and a forage biomass of 11 t ha^{-1} and 3 t ha^{-1} were produced under rain-fed conditions in 2003 and 2005, respectively. Under irrigation conditions and taking advantage of lucerne winter dormancy, oat was sown and a silage biomass of 25 t ha^{-1} plus a hay biomass of 7.5 t ha^{-1} were harvested in two adjacent fields.

Effect of organic and inorganic fertilizers on the yield of maize and common bean/soybean intercrops in Mozambique

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The beneficial effects of combining legumes with organic and inorganic nutrient sources were investigated using maize as a test crop at Lichinga and Sussudenga Research Stations in Mozambique. The experiments consisted of two factors, i.e., cropping systems; maize/soybean and maize/common bean intercrops and five fertilizer treatments; T2 = cow manure (5 ton ha^{-1}), T3 = cow manure 2.5 ton ha^{-1}+ 50 kg NPK, T4 = cow manure 1.25 ton ha^{-1}+ 100 kg NPK (12:24:12), T5 = NPK (12:24:12) 200 kg ha^{-1}. The trials were laid out as randomized complete block design with a factorial arrangement replicated three times with a control (T1). The experimental results showed that there were no significant differences ($P > 0.05$) in the vegetative growth of maize for the various treatments; however, the treatments gave higher values of stover, plant height, 100 seed weight and yields in Sussudenga than in Lichinga. The results showed that the sowing of maize in mixture with common bean improved maize plant height but it was reduced when sown in mixture with soybean in both locations. The mixtures of maize + common bean and maize + soybean in Sussudenga gave higher maize yield than in Lichinga. The maize yields obtained by the combined treatments were significantly higher in T4 treatment than the other treatments in both locations. Common bean and soybean produced in Lichinga appeared to be more compatible regarding to Sussudenga yields. Survey was conducted in both districts and total sample size was 80 farmers. The objective of the survey was to investigate key limiting production constraints of maize, the factors influencing farmers' decisions making on fertilizer use and to evaluate the farmers' risk perceptions and adaptation to climate change. Data analysis was performed using SPSS (2007). Farmers in Lichinga grow their crops in intercrop while in Sussudenga they grow their crops in mono cropping. The reasons appointed by the farmer to use intercropping In Lichinga are better management of farmer, labour and increase production while in Sussudenga the farmer use mono cropping to avoid competition between the crops. Labour, inputs and Extension Assistance are constraints that farmer fence to improve maize production. to cope with the constraints farmers adopt some strategies like application of crop residues, buy small amount of NPK, look for assistance from other and hire oxen labour. Price, information access, market availability and inexistence of subside programs significantly affected the probability of using organic or inorganic fertilizers. Farmers in Sussudenga (45%) and Lichinga (40%) indicated that they have experienced any unusual weather conditions over the past ten years. The farmer from both sites believes that they are severely affected by rainfall variability and higher temperatures and farmer also highlighted that now they were experiencing shorter rain seasons than before. Growing drought tolerant crops, such as cassava, Sweet potato and cultivation of horticultural crops in wetlands as well as the use of different maize varieties are common strategies among the households to cope with the climate change.

Empowering communities to adapt to climate change through field-based Learning Centres in Zimbabwe

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Smallholder farmers in sub-Saharan Africa have over years developed low risk farming management practices in an effort to ensure that their subsistence food needs are met. However, farmers' practices are largely sub-optimal even under favourable climatic conditions as they are faced with multiple biophysical and socio-economic stresses that are now exacerbated by increased rainfall variability. Evidence from empirical research indicates that it is possible for farmers to increase maize yields from the current 1 t ha^{-1} to 3 t ha^{-1} if appropriate technologies are adopted, and when rainfall is adequate. A three-year study was conducted with six smallholder farming communities in eastern Zimbabwe to develop crop production strategies that respond to the emerging challenges of increased climate variability. Using farmer participatory research approaches, field-based Learning Centres were established to analyse the implications of emerging rainfall patterns and develop matching crop management options for adaptation. Focusing on co-learning of technical options drawn from both farmers' local experiences and findings of empirical research, planting windows, crop types and components of integrated soil fertility management (ISFM) were evaluated through participatory experimentation. Successful mobilization of farmers and service providers resulted in a rapid increase of climate change adaptation Learning Centres from six to 42 over three seasons. The study revealed substantial variability in performance of maize varieties across seasons and sites, increasing community consciousness on the magnitude of pending challenges associated with climate change and variability. Use of combinations of locally available organic nutrient resources and external fertilizers provided an opportunity to produce yields ranging from 3-7 t ha^{-1} when planting was done in the early (25 October-25 November) and normal (26 November-15 December) planting windows. However, only early planted drought tolerant maize varieties successfully yielded grain during the 2007/08 season, with yields of up to 3 t ha^{-1}. Across the different study sites, farmers clearly identified emerging seasonal rainfall typologies determining their food security and livelihoods: (i) normal rainfall seasons (ii) excessive rainfall during first half of season followed by drought (iii) early season drought and (iv) seasons with marked within-season dry spells.Aggregated results suggested that farmers in high potential regions had a 0.67 probability of obtaining 3-7 t ha^{-1} grain yields with a combination of early planting and good nutrient management practices. The results also suggest that there remains an unacceptability high probability (0.33) of having sub-economic yields even with good nutrient management and early planting, due to sensitive crop growth stages coinciding with severe dry spells early in the season. Yield losses of 30-60% occurred when planting was delayed by 3-6 weeks from the onset of the rains. Development of crop and soil fertility management options around rainfall season typologies identified by farmers could enhance the capacity of smallholders to increase crop productivity and ensure food self-sufficiency against a changing climate.

Effect of plant density and mineral fertilizer application on yield of two groundnut varieties in northern Mozambique

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Groundnut (*Arachis hypogaea* L) is a source of dietary protein and oil, and an important cash crop for the rural poor in northern Mozambique. As a legume, it contributes to soil fertility through nitrogen fixation and constitutes an important component of the agricultural production system. However, yields are limited by lack of improved varieties, poor cultural practices and low use of mineral fertilizers. Field trials were conducted in 2012 at two sites: Muriaze and Nametil in Nampula province to evaluate the responses of two groundnut varieties to phosphorus, lime and starter nitrogen application using two row spacing (50x15 cm and 75x20 cm). Two varieties, Nametil and Mamane were used and P was applied at 0 or 20 kg/ha, lime at 0 or 100 kg/ha and N at 0 or 40 kg/ha. A split plot design was used with a factorial combination of varieties with mineral fertilizer application (treatments) as main plot and row spacing as sub-plots. Plant samples were taken at flowering for nodulation and biomass assessment and plots were harvested at maturity to determine grain yield. Significant differences ($p < 0.05$) were noted among Treatment x Site x Row spacing interaction. Treatments, Sites and Row spacing were significant ($p < 0.05$) for grain yield (ton/ha), pod load, empty pod number/plant, seed size and rosette infestation (%). Nametil Site produced high mean grain yield (3.77 ton/ha) and low mean empty pod number/plant (3). Muriaze Site produced high mean nodule number/plant (127), high mean 100 nodule weight (0.31g) and low mean shelling (34%). Row spacing did not affect mean nodules number/plant and mean 100 nodule weight but it affected on grain yield, the row spacing 75x20 cm were high (3.58 ton/ha) and the row spacing 50x15cm were high (33.08 g/plant). The grain yield (ton/ha) showed to be affected by treatments, Nametil+none (1.94 ton/ha) and Mamane+none (1.54 ton/ha) and, pod load of Nametil+none (21) and Mamane+none (19) were lowest. The correlation analyses revealed that yield components (seed size and pod load), growth parameters (RSR, nodule number/plant, root biomass weight) and shelling were positively correlated with grain yield at Nametil site and growth parameters (plant height and shoot biomass weight) were positively correlated with grain yield at Muriaze site.

Response of *Corchorus olitorius* to arbuscular mycorrhizae, poultry manure and inorganic fertilizer

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Five accession of *Corchorus olitorius* obtained from two teaching and research and institutions in Nigeria were used to access the effect the effect of arbuscular mycorrhizal (AM) poultry manure (PM), inorganic fertilizer (NPK), and the synergy of AM and PM on the growth and yield of *C. olitorius*. The experiment was a 5x5 factorial laid out in a randomized complete block design with 3-replication. The experiment was conducted in the teaching and research farm of the Department of Agriculture Babcock University, between November 2011 to February 2012. Data were collected on seven yield related characters. The combined ANOVA showed significant treatment, accession, replication and accession x treatment interaction effect on majority of the traits evaluated at 0.01 and 0.05 probabilities. AM-PM treatment produced significantly higher weight of pod per plant suggesting that AM-PM treatment has high potential in influencing high crop yield even above NPK. There was significant positive correlation between weights of leaf per plant and plant height at maturity and number of branches per plant at maturity, suggesting that, selection directed toward plant height and number of branches will enhance leaf yield. Accession BUCR7 and BUCR9 were best in number of leaves per plant, weight of leaves per plant and number of pods per plant all at maturity and can be considered as parents in breeding for leafy vegetable yield.

Symbiotic rhizobia are key to enhanced soil fertility, increased crop yields and improved human health

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Soil bacteria belonging to the genera *Rhizobium*, *Bradyrhizobium*, *Sinorhizobium* (*Ensife*r), *Mesorhizobium* and *Azorhizobium* (generically referred to as "rhizobia") are capable of eliciting nodule formation and synthezing nitrogenase enzyme that reduces N_2 to NH_3 in root nodules, leading to elevated symbiotic N yield, which in turn triggers increased photosynthetic rates, enhanced C accumulation (or plant growth), and a heightened accumulation of nutrient elements in organs of the host plant. The net result, for a very effective host/strain symbiosis, is increased protein level, greater concentrations of mineral nutrients (especially trace elements) in edible plant parts, and higher grain yield. We have shown, using different legume symbioses under strict microbiological conditions in Leonard jars, that the N_2-fixing efficacy of a rhizobial strain is the major determinant of host-plant functioning, which includes photosynthesis, mineral nutrition, and grain yield. We also have demonstrated, using cowpea in field experiments, that high N_2-fixing symbioses consistently exhibit greater plant growth, grain yield and mineral accumulation. This was in contrast to the low N_2-fixing genotypes, which always revealed decreased photosynthetic rates, small plant biomass, reduced grain yield, and lowered mineral accumulation in plant organs. Nutritionally, the high protein and mineral density in edible plant parts have the potential to improve human nutrition and health, especially against protein-calorie malnutrition and disorders emanating from micronutrient deficiency. In agronomic terms, the high N contribution and increased mineral accumulation from efficient symbioses also have the potential to improve soil fertility in cropping systems, and thus increase the benefits of legume rotation with cereal crops. In this paper, we discuss symbiotic rhizobia askey players in enhancing soil fertility, increasing crop yields, as well as improving human nutrition and health.

Mycorrhizal agrotechnology for Africa: Challenges and future Prospects

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Mycorrhizal fungi are well known symbionts of many agricultural crops and the role they play in enhanced nutrient acquisition and plant growth promotion has been published extensively in several thousands of peer reviewed journal articles. The production of mycorrhizal inoculants is achieved using a limited range of methodologies by more than 15 companies worldwide. The use of biofertilizers such as N-fixing bacteria has had a long standing history of use in many countries and is perhaps the most successful microbial inoculants ever produced. According to the FAO report on 'The State of Food and Agriculture 2010-2011', 26% of the world's 925 million hungry people are in sub-Saharan Africa. Ensuring food security is about alleviating hunger and malnutrition, but also needs to address the adoption of improved and innovative agricultural technologies. Given the many benefits of harnessing mycorrhizal fungi in an effort to reduce agrochemical inputs and improving soil health, crop production and quality the question remains: *Why have we not embraced mycorrhizal technology and adopted it as standard agricultural practice in Africa?* The answer could be related to production constraints, quality control, maintenance of culture collections, species/host matching. Alternatively the problems may be market related due difficulties related to product registration, lack of market knowledge and farmer perception. The biggest challenge may be due to the cost of these technologies and inability of resource poor farmers in particular to successfully exploit this technology. This presentation will examine these challenges and identify potential bottlenecks in the adoption of mycorrhizal technologies, suggest alternative approaches, such as on-farm inoculant production and highlight areas of research needing attention in the African context.

Influence of mycorrhizal helper bacteria on arbuscular mycorrhizal fungi

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Arbuscular mycorrhizal fungi associate synergistically with bacteria to stimulate plant growth by a range of mechanisms. The purpose of the study was to investigate if bacterial isolates associated with *Glomus mosseae* spores show Mycorrhizal Helper Bacteria and Plant Growth Promoting Rhizobacteria (PGPR) characteristics. Bacteria were isolated from the external and internal surfaces of the spores and tested for phosphate solubilisation, indole acetic acid (IAA) production and fungal pathogen inhibition. A total of seven isolates showed potential to be PGPR as four isolates were able to solubilise the phosphate source $CaHPO_3$, of which one isolate was also able to produce IAA. The remaining three isolates showed inhibition of the fungal pathogens *Fusarium oxysporum* ssp *lycopersici*, *Pythium aphanidermatum* and *Verticillium dahliae* in vitro. These bacterial isolates were selected for further pot trial analysis to test the influence of the isolates on plant growth and AM colonisation. There was a significant difference in shoot height among the bacterial treatments, however no significant differences in root or shoot dry weight was found. A signifcant difference in the bacterial treatments on the colonisation of *G. mosseae* was found. The bacterial isolate which solubilised phosphate and produced IAA significantly increased percentage mycorrhizal colonisation and can be regarded as Mycorrhizal Helper Bacteria. It can be concluded that bacterial isolates from the spores of *G. mosseae* have the potential to assist with colonisation as well as enhance the mycorrhizal benefits to the host plant.

Partnering in agricultural technology dissemination: A comparative case study of N2Africa partner organisations

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While different organizational models have been used for the dissemination of new agricultural technologies to smallholder farmers, the dominant model deployed in (donor-funded) agricultural intervention in Africa builds on partner organizations. NGOs, CBOs and national agricultural extension services constitute the implementing partners, with whom activities and outcomes are agreed upon, and to whom donor funds and technical backstopping is channelled. There is surprisingly little documentation of such partnerships and particularly of their effectiveness in dissemination. The N2Africa project aims to disseminate legume technologies to small-scale African farmers to achieve goals of improving soil fertility, farmers' livelihoods and food security in eight countries in Sub-Saharan Africa. All N2Africa dissemination efforts are directed through partner organisations. This paper builds on the experiences of the N2Africa project to explore organisational characteristics that may be indicative for effectiveness in dissemination. Within N2Africa we have begun to systematically characterize partner organisations to assess effectiveness in dissemination, and make a comparative analyses of 'best-bet' dissemination practices both within and between countries. Preliminary analyses show that the effectiveness of dissemination efforts is related to the number of years an organization has been operating in a given country, the longevity of its farmer groups and the focus of the organisation.

Diversity and specificity of fungal communities associated with *Angraecum bory* in Atlantic Central Africa

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There is increasing number of studies about the genetic and functional diversity of fungal communities associated with temperate terrestrial and neotropical epiphytic orchids. However, little is known about the fungal partners of epiphytic orchids of tropical Africa. The present study was undertaken to determine the mycorrhizal status and to identify the fungal communities associated with epiphytic orchids in Atlantic Central Africa. Therefore, roots were collected from ten species of epiphytic orchids belonging to the genus *Angraecum*, from Cameroon, Gabon and São Tome and Principe. All examined orchid species were mycorrhized. The analysis of fungal ITS (Internal Transcribed Spacer) sequences revealed a high diversity of fungi in orchid roots, including mycorrhizal, saprotrophic and parasitic species. However, only a few fungal taxa were shared by different orchid species, suggesting a host preference. The members of *Tulasnellales* are the most frequent fungal symbionts associated with analyzed roots. These fungi may play an important role in the carbon and nutrient budgets of African epiphytic orchids. Future research should aim at quantifying the contribution of these fungi to growth of epiphytic orchids.

Effects of *Jatropha curcas* monoculture on soil micro-sumbionts in Senegal

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Jatropha curcas L., an *Euphorbiaceae* native of Central America, is a woody shrub valorized for the medicinal properties of its leaves, bark or sap as well as a good candidate to vegetalise degraded lands owing to its ability to withstand nutrient and hydric stresses. It has also been identified in recent years to be suitable to agro-fuel production in tropical and subtropical areas. A national program was developed in Senegal in 2008 with an objective of 300,000 hectares by 2012. However, there is a lack of

studies dedicated to its effects on native plants/soil microorganisms interactions although it is known that this shrub releases various toxic compounds in soil (e.g. phorbol esters, curcins, trypsin inhibitors) through rhizodeposition and litter decomposition. Since soil microbial functionnal diversity, especially mycorrhizal and rhizobial diversity, are essential to productivity and diversity and plants communities, it is important to evaluate the impact of *J. curcas* monoculture on these plants/microbes interactions. In this background, our study aimed to evaluate to which extent *J. curcas* could affect the growth and symbiotic status (arbuscular mycorrhizal fungi, rhizobia) of local plant species cultivated on soils transferred from *J. curcas* fields. Pearl millet (*Pennisetum glaucum*), cowpea (*Vigna unguiculata*) and acacia (*Acacia seyal*) were grown in a greenhouse for several weeks or months on soil samples transferred from three *J. curcas* fields and their adjacent fallow plots (control soils). Measurements of shoot and root biomass, and the percentages of root mycorrhization, advocated for an overall positive influence of *J. curcas* as compared to scores obtained with control soils. However, the intensity of mycorrhization was unaffected by the soil origin. Analyzis of the molecular diversity of root AMF by 18S ribosomal gene sequencing revealed that the composition of the mycorrhizal community was systematically different between control and *J. curcas* soils. When cowpea was grown on *J. curcas* soils, the number of nodules was significantly lower and their individual weight higher than with control soils. The composition of the rhizobial communities nodulating cowpea and acacia roots was studied by *nifH* gene sequencing. No significant modification of the rhizobial assemblages was evidenced except with that of acacia growing in soil sampled from one of the three sites : *nifH* sequences were affiliated to the genus *Mesorhizobium* in the case of *J. curcas* soil and to *Bradyrhizobium* in the case of control soil. Overall, these results indicate that the microsymbionts communities were sensitive to the *J. curcas* monoculture mostly in terms of diversity for the mycorrhizal fungi and nodulation rates for the rhizobia but these microbial shifts did not negatively impact the early developmental stages of the tested plants. However, evaluation of the soil microflora resistance to various abiotic stresses is necessary to complete the assessment of the ecological impact of *J. curcas*.

Producing microbial inoculants for eco-agriculture in agroecosystems of Central Africa

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Microbial inoculants must be developed for soil fertility, crop production and soil conservation in sub-Saharan Africa. Their importance is still underestimated by scientists or ignored by extension agents and farmers. What is the potential and economic value of microbial inoculants for agricultural sector in African countries? Can we develop micro-projects involving small enterprises for microbial inoculants in Central Africa? Examples are selected N-fixing bacteria for legumes and mycorrhizal fungi (AMF) for most crops and trees. AMF have multi-functional properties: may improve on nutrient cycling and uptake, drought stress, pest and disease tolerance and environmental services. They are tested after selection, production and evaluation under nursery and field conditions in diverse agro-ecological zones in Cameroon since 1991. Research carried out for more than 20 years has provided significant results on diverse soils types. Inoculation of legumes by rhizobia, and garden crops, cereals, legumes, tubers or trees by AMF have increased crop yield by 50% to more than 200%. The potential quantity of AMF inoculants (as soil-based) to apply yearly to only 10% of new cultivated area is about 110,130 tons. For major crops such as banana, cassava, cocoa, coffee, cotton, oil palm, plantain, rice, sorghum/millet, sugar cane, it is 356,106 ha area for 64,660 tons of AMF yearly. This quantity can be strongly reduced using plant, soil biotechnology and tissue culture techniques or increase if biofuel crops or trees planting programmes are considered. For the major grain legumes, the quantity of rhizobial inoculants to apply yearly for only 10% cultivated area is 64 tons. A UNESCO microbial resource center is lacking for Central African region it should be created for developing microbial inoculants industries. Such microbial technology should be the basis for a green economy in sub-Saharan Africa. Before that, experiments for facilitating application and adoption of microbial inoculants for various cropping systems should be carried out. Also, capacity building for African farmers on bio-fertilizers' use and benefits has to be done. Technologies for large scale production of concentrated quality products should be set up, developed and transferred to local industries with property right consideration. Multi-actors processes, like Model Forest, AGRA and CIAT could play a key role for the integration of those stakeholders and the development of beneficial microbial inoculants markets and a greener agricultural economy at the landscape, national and regional level in Central Africa and beyond.

Diversité des champignons mycorhiziens arbusculaires associés au *Vigna unguiculata* en fonction de la typologie des sols au Sénégal

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Au nord (zone Sahélienne) et au centre du Sénégal (zone Soudano-Sahélienne), les sols de culture sont essentiellement de trois types : des sols ferrugineux tropicaux faiblement lessivés sur sable localement appelés « DIOR », des sols à hydromorphie temporaire de surface sur sable et marno-calcaire appelé « DEK » et des sols intermédiaires entre les deux premiers appelés « DEK-DIOR ». Dans ce présent travail, nous avons étudié la diversité des champignons mycorhiziens arbusculaires dans les trois types de sols prélevés dans deux sites des deux zones éco-climatiques différentes. Dans chacun de ces deux sites, les échantillonnages ont été réalisés dans neuf parcelles dont trois de type DEK, trois de types DEK-DIOR et trois autres de type DIOR. Les échantillonnages de sols ont été réalisés en saison sèche et pour chaque type de sol, un échantillon composite a été réalisé avec les prélèvements effectués sur les trois parcelles. Une partie de l'échantillon a été utilisée pour faire un piégeage des champignons MA en serre avec du niébé comme plante piège. Les études de diversités et de densités des champignons MA sont effectuées sur les sols avant et après piégeage. Pour étudier la diversité et la densité des champignons MA, nous avons utilisé la méthode du tamisage humide décrite par Gerdemann et Nicolson, 1963. Les différents morphotypes isolés sont observés et

décrits pour une première identification suivant leurs caractéristiques morphologiques et anatomiques après montage dans du PVLG et PVLG+liquide de Melzer. Nos résultats montrent que lafamille des *Glomeraceae* est la plus représentée aussi bien dans les parcelles de la zone soudano-sahélienne que celles de la zone sahélienne. Elle regroupe 50% des espèces récoltées. Elle est ensuite suivie de la famille des *Aucaulosporaceae* avec quatre espèces, soit 33,33% des espèces. La famille des *Gigasporaceae* avec les genres *Scutellospora* et *Gigaspora* regroupe 16.66% des espèces récoltées. La structure des CMA a été également déterminée en calculant des indices de diversité. Les résultats obtenus révèlent, aussi bien sur les sols avant et après piégeage, une répartition des espèces beaucoup plus régulière dans les sols intermédiaires (DEK-DIOR) quelque soit l'origine du sol. Quant à la densité des spores, l'étude a montré que globalement le nombre de spores de *Scutellospora gregaria* ne varie pas en fonction du type de sol alors que pour les autres espèces, les densités varient significativement en fonction du type de sol. *Gigaspora rosea*, et les espèces du genre *Glomus* présentent généralement des densités significativement plus importantes dans les sols DEK et DEK-DIOR. Pour le genre *Acaulospora*, les densités de spores semblent dépendre à la fois du type de sol et de la zones éco-climatique. Elles sont plus importantes au nord dans les sols DEK et DEK-DIOR alors qu'au centre, elles restent dominantes dans les sols DIOR.

Socio-economic analysis of legume production among smallholder farmers in Zimbabwe

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Zimbabwean smallholder agriculture is characterized by low productivity that rarely exceeds 1t/ha for cereals and 0.5/ha for grain legume due to severe nutrient depletion or mining among other factors. This research was carried out to identify factors affecting legume cultivation. To achieve this, rapid rural appraisal approach was employed to collect data on farmer's perceptions of factors affecting legume production. Data were collected from four districts differentiated by agro-ecological potential and market access. Descriptive analysis was used to summarise data and prioritise factors affecting legume production. Farmers cited unavailability of inputs, lack of markets, low prices, lack of knowledge, gender issues, inadequate rains, pests and diseases, land and labour constraints as the major factors affecting production with the percentage ratings of 93%, 91%, 89%, 56%, 52%, 65%, 40%, 33% and 42%, respectively. In light of these outcomes so far, the analysis concludes that for successful promotion of legumes, efforts should be directed towards providing input and output markets, favourable prices for legumes, more extension support to improve knowledge on legume production as well as pest and disease management. It is also imperative to provide farmers with labour saving techniques, mitigation and adaptation strategies to climate change, increase land access as well as gender mainstreaming in legume production. To address these challenges, the promotion of legumes should be a multi-sectoral approach given the nature of constraints that require the involvement of both the government and the private sector. The government should formulate policies that address land access issues, provide more knowledge through extension services and promote male involvement in legume cultivation. The private sector too, should work towards availing input and output markets for legumes through programs such as contract farming. There is need for employing regression analysis to quantify the exact effect of each factor on legume production.

Use of arbuscular mycorrhizal fungi as bioenhancers: are we ready?

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Management of soil biota as providers of key ecological services has received an increasing attention in the past years. These organisms, often referred to as 'ecosystem engineers', 'biocontrol agents' 'biofertilizers' or 'bioenhancers', when released in the environment, can participate in restoring ecosystems, combating pollution and pests, or improving plant growth and nutrition. One of the most important providers of these ecological services is the association formed between plant roots and arbuscular mycorrhizal (AM) fungi. The large majority of land plants, including most of agricultural crops, form arbuscular mycorrhizas, whose main beneficial effect for plants resides in improved soil exploitation thanks to their extraradical hyphal network. This hyphal network thus allows the plants to acquire, far beyond the rhizosphere, poorly available soil mineral nutrients, such as phosphorus. Due to their function in plant nutrient acquisition, AM fungi are considered as key partners to increase plant growth in nutrient-poor soils. Bioenhancement through their deliberate released could be profitable in low-input agriculture as suggested by numerous studies. However, whether a particular fungal strain is effective in promoting crop yield, can be mass-produced and efficiently formulated, is able to persist among indigenous AM fungal strains, or can endure a particular environment or cultural practices, are some of the questions we must urgently answer. Activities conducted in the Center of Study on AM Monoxenics aim at better understanding whether and how AM fungi could be used in agriculture. Examples taken from the latest development of our research activities will be used in this presentation. In particular, the aspects of screening, mass-production, formulation and application of AM fungi will be discussed. Potential and advantages of *in vitro* cultivation of AM fungi for answering tomorrow's challenges of a more convincing and efficient use of these bioenhancers will also be given through these examples.

Analyse socioéconomique des stratégies de conservation de l'eau et des sols au Nord-ouest du Bénin

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Cette étude vise à analyser du point de vue socioéconomique les stratégies de conservation de l'eau et des sols au Nord-Ouest du Bénin. Elle a été effectuée dans les communes de Ouaké et de Boukombé. Six villages à raison de trois par commune ont été choisis de façon aléatoire pour abriter cette étude. Au total, 180 producteurs dont 30 par village ont été enquêtés de façon aléatoire. Les différentes stratégies de conservation de l'eau et des sols utilisées et leur origine, les caractéristiques socioéconomiques des ménages, les cultures bénéficiant de chaque stratégie, le relief de chaque sol lié à chaque stratégie, la fréquence de consommation alimentaire et le revenu issu de la production ont été collectés lors des entretiens individuels semi-structurés et ouverts à l'aide d'un questionnaire. La régression logistique multinomiale a permis d'identifier les déterminants de chaque stratégie. Le test de comparaison de moyennes a permis d'identifier le groupe de stratégies le plus rentable et celui garantissant plus une meilleure sécurité alimentaire.Le nid d'abeille, les billons en courbe de niveau, les cordons pierreux, les banquettes, les billons cloisonnés, les ados et les billons perpendiculaires à la pente sont les principales stratégies utilisées pour la conservation de l'eau et des sols à Boukombé tandis qu'à Ouaké les stratégies les plus utilisées sont les billons cloisonnés, les ados et les billons perpendiculaires à la pente. Leur utilisation varie suivant les reliefs et est déterminée par les caractéristiques socioéconomiques des ménages. Certaines stratégies (banquette, ados) ont été introduites par les structures de développement tandis que d'autres (billons perpendiculaires à la pente, billons cloisonnés, le nid d'abeille, les billons en courbe de niveau et les cordons pierreux) sont endogènes. Dans le but de mieux conserver l'eau et les sols, les producteurs combinent les stratégies. La combinaison de certaines stratégies améliore plus le revenu des producteurs tandis que la combinaison d'autres garantit plus la sécurité alimentaire des ménages. En définitive, les producteurs n'utilisent pas une seule stratégie dans leur exploitation. Ils les combinent dans le but de maximiser le rendement de leur production agricole.

Soil fertility innovations through agroforestry management in sub-Saharan Africa

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Land degradation and declining soil fertility are increasing being viewed as critical problems affecting agricultural productivity and human welfare in the tropical Africa. Improving soil fertility is the key entry point for achieving food security, reducing poverty and preserving the environment for smallholder farms in sub-Sahara Africa. Given the high cost of inorganic fertilizers, an integrated approach that combines promising agroforestry technologies particularly improved fallows and biomass transfer with locally available and reactive phosphate rock is important. This paper found that improved fallows of leguminous species and biomass transfer are both promising agroforestry techniques that can contribute to integrated soil fertility management practices in smallholder farms. They can also provide other benefits such as control of pest and diseases and provide fuelwood that is in short supply in many rural settings. The paper recommends that developing strategies to make fertilizers affordable, promoting widely synergistic technologies such as biological soil and water conservation measures, assessing ecological benefits of fallow plant species while mitigating potential problems of them becoming invasive weed are paramount for food security it is important to determine ways in which high value trees, crops and livestock can be more intensively farmed providing a natural progression out of poverty.

Agro-input dealer suitability for disseminating and communicating soil fertility management practices: The case of Siaya and Trans Nzoia Counties, Kenya

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Lack of access to necessary agro-inputs contributes to low agricultural productivity and slows the overall economic growth and development in most parts of sub-Saharan Africa. Agro-input dealers make inputs more easily accessible to rural-based smallholder farmers. Despite their importance, little is known about the strategies agro-input dealers use in the dissemination and communication of information and knowledge on agricultural technologies. This study assessed the role played by agro-input dealers in disseminating and communicating integrated soil fertility management (ISFM) practices and information to smallholder farmers. The study conducted in Siaya and Trans Nzoia countries in Kenya, looked at the agro-input dealer's awareness of ISFM practices communication channels used to access agricultural information, the support services offered to farmers and also assessed the agro-input dealers willingness to pay (WTP) for the communication tools that can help them better communicate soil fertility management practices to their clients. The study interviewed 144 agro-input dealers randomly selected across the study area. Two surveys were conducted with the first survey focusing on awareness of ISFM practices, communication channels and support services provided to farmers while the second on the WTP for two agriculture technology communication tools (Maize Doctor and Soil Map).The result from logit analysis showed that gender, age, educational level, experience in agro-input business and visit by extension staff significantly influenced the agro-dealers' awareness of ISFM technologies. Paired sample T-test on the mean numbers of farmers that benefitted from the support service from agro-input dealers showed a significant difference across gender of the farmers. Factor analysis indicated that community based (Cosmopolite interpersonal) channels of communication were the most preferred communication channels among the agro-dealer network in two study areas. Male agro-dealers were willing to pay more for the Maize doctor and Soil map tools

compared to female agro-dealers. Also agro-dealers with more education and those who had been visited by extension agents and researchers were willing to pay more compared to those with less education and had not been visited by extension agents and researchers. The study noted the important role played by community based channels of communication in the ISFM knowledge dissemination. The study suggests the need to improve the provision of extension services to agro-dealers to enable them effectively communicate information about ISFM technologies to farmers. Such initiatives on capacity building should take into consideration gender of the agro-input dealers.

Rhizobial inoculation: a promising way to improve plant growth and productivity in saline and dry conditions

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The main problem in many of African countries is related to poor environmental conditions in arid and semi-arid areas, where the local populations are poor and facing food security problems. Salinity and drought are an increasing environmental problem and represent major limiting factors in crop production and ecological environment building-up, especially in arid and semiarid regions. Legumes are agronomically and economically important due to their ability to fix atmospheric nitrogen with the help of rhizobial strains. However, in order to ensure optimal exploitation of their economic and agricultural potential, it is necessary to go for inoculation using effective symbionts. In this context, we carried out two experiments in order to evaluate the impact of inoculation with selected rhizobial strains on *Acacia seyal* and *A. senegal* tolerance to salinity and drought, respectively. The first experiment analyzed the effects of inoculation with two rhizobial strains (ORS 3394 and ORS 3403) on growth, physiological, and biochemical responses of *A. seyal* seedlings cultivated in vitro at four levels (0, 85, 171, and 256 mM) of NaCl. The second experiment examined the efficiency of three rhizobial strains (ORS 3416, ORS 3428 and ORS 3437) for nodulating and improving *A. senegal* growth and productivity in the greenhouse under water-limited conditions. The effect of rhizobial inoculation on growth of *A. senegal* plants was examined under non-limited (100% of water holding capacity, WHC) and water-limited conditions (50% WHC) in the greenhouse for four months on non-sterile sandy soil. Results showed that salt stress gradually decreased the nodulation, growth, the soluble protein and the leaf-chlorophyll contents of *A. seyal* seedlings. However, rhizobial inoculation limited these adverse effects of salt on physiological and metabolic processes responses. *A. seyal* exhibited a moderate halophytic behavior nodulation was enhanced by moderate salt stress. The greenhouse experiment showed a significant decrease in the nodulation rate, nodule dry weight, plant height and shoot dry weight under water-limited conditions. Nevertheless, inoculation with rhizobial strains significantly improved nodulation and *A. senegal* plant growth and shoot dry weight and nitrogen content under water-limited conditions. Our results showed that inoculation with selected rhizobial strains can be an effective way to improve plant growth and productivity in saline and dry environments and also increase carbon sequestration.

Timing of myccorrhiza inoculation on cacao seedling development

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Experiments were conducted between April-August, 2009 and January- May, 2010 at the Federal University of Technology, Akure, Nigeria. Studies were conducted to evaluate the effects of varying time of application of arboscular mycorrhiza fungi (AMF) inoculum on vigour of growth and root development of cacao seedlings in the nursery. The results show that application of AMF at planting zero (0), four (4), and eight (8) weeks after sowing of cacao seeds favoured shoot and root development over the control treatment. Significantly higher mean values were recorded with application of AMF at 0, 4 and 8 weeks after sowing in term of numbers of leaves produced, leaf area, plant height, and the number of lateral roots over the control, 12 and 16 weeks treatments. Distribution of lateral roots along the tap root in application at planting treatment and four (4) weeks after sowing were more uniform down the tap root compared with higher concentration towards the soil surface in 12 and 16 weeks treatments. The vigour of plant growth and root volume which determines field establishment was observed to be better with 4 and 8 weeks treatments. A significantly higher spore count was recorded in 0 and 4 treatment application compared with other treatments. The result of the studies shows the capability of AMF enhancing cacao seedling growth and development if applied at the early stage in the nursery.

Yield and soil properties as affected by fertilizer microdosing in millet-based systems of the Sahel

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In West African drylands, improved soil fertility is required if farmers are to capture the high yield potential of improved germplasm already available. However average rate of nutrient usage in sub-Saharan Africa is less than 10 kg per hectare. The microdosing technology, strategic placement of small amount of fertilizer close to the planting hill at planting, was developed by ICRISAT and partners to lower the amount of fertilizer needed per cropped area and at the same time improve crop yield and nutrient use efficiency. Studies conducted so far have reported yield increase of 50–120%. Such a high yield increase implies consequent nutrient uptake. Considering that common practice of the farmers of the dryland area is the total removal of residue from the field or total consumption by roaming animals leaving very little organic matter, there is the risk that nutrient

imbalances will develop following continuous application of the fertilizer microdosing technology. To study the long term effect of the technology on crop yield and soil characteristics, an experiment was conducted at ICRISAT research station at Sadore from 2003 to 2007 in an RCBD design that involved millet varieties HKP and Sadore local planted in 5000, 10000 and 15000 hills per ha densities with 3 g or 6 g NPK per planting hill or 2 g DAP + 1g urea per hill and a control without any fertilizer input. Crop residues were removed after harvest. Grain yield was lower in the control plot across years. The lower the planting density the lower was grain yield. However grain yields of 10000 and 15000 hill per ha were similar. Sadore local variety performed better than HKP the improved one in terms of grain and stover yield across years. Grain yield dropped by 72% on average from year one to year three. The least yield decrease was observed with 6g NPK per hill (28%). Negative N and K balance was observed in all plots whereas for P this occurred only in the control plots. These results show that increased biomass production leading to nutrient uptake may worsen the already fragile fertility level of the dryland soil in terms of N and K content if there is no adequate measures for organic matter build up following spot application of fertilizer microdosing. Phosphorus balance was still positive after three years even though yield dropped. This trend could be due to the low initial level in the study field but also low crop uptake, however, extending the study over a longer period is necessary for a stronger conclusion.

Genetic and nutrient management options to raise pearl millet productivity under smallholder conditions

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One of the constraints to agricultural production in the Sahel is low external input use due to their limited availability and relatively high price. To help increase the rate of on-farm application of sources of nutrients, the so-called fertilizer microdosing technology was developed by ICRISAT and partners and demonstrated in farmers' field with promising results. Organic amendments constitute the principal source of nutrients for agriculture under Sahelian conditions. Hill application of manure combined with mineral fertilizer microdose is an option to optimize the yield response of a given quantity of both fertilizers, but also to ensure fertilization and sustain crop production of a larger surface area. A study involving 16 options of nutrients management (combination of different rates of organic and mineral fertilizers) and 10 millet genotypes was conducted at ICRISAT research station at Sadore in a randomized complete block design with 3 replications for two years. The objective was to evaluate crop performance under various nutrient management conditions and to determine the optimal combination of the genotype, fertilizer microdosing and organic amendment application for agronomic and economic parameters. Ten millet genotypes, 9 ICRISAT improved and 1 local, were tested with the combination of 4 organic manure application rates (0 g, 100 g, 200 g and 300 g/hill) equivalent to 0 kg, 1000 kg, 2000 kg and 3000 kg ha^{-1} respectively. The 4 mineral fertilizer application options were 0 g, 2 g DAP + 1g urea, 3 g and 6 g NPK equivalent to 0 kg, 20 kg (DAP) + 10 kg (urea), 30 kg and 60 kg ha^{-1} respectively. All fertilizers were applied on the planting hill on the day of planting except for urea which was applied at the stage of stem elongation. In 2010, no significant effect of organic or mineral fertilizer was observed while significant genotypic differences were observed for grains, panicle and stover yields. In 2011, stover, panicle and grains yields increased with the rate of manure application with an average yield of 1045 $kg.ha^{-1}$ for 300g per hill. Application 6 g inorganic fertilizer per hill produced significantly higher grains yield than other fertilizer treatments. The genotypic performance was similar to 2010. Significant year and year by treatment effects were observed for grain, panicle and stover yields. Applying 6 kg NPK was the most beneficial option with 27300 frs cfa ha^{-1} followed by 300 g per hill of organic manure. The combination of 300 g of organic manure with 6 g of NPK per hill resulted in a benefit of 19475 frs cfa ha^{-1}. This indicates that applying one source of nutrient is the best option for the famer.

Effectiveness of marketed arbuscular mycorrhizal fungi inoculants on soybean in Kenya

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Effectiveness of commercialized plant growth promoters vary considerably with microbial composition, strain density and suitability to adapt into local environmental context such as soil P level and indigenous AMF competiveness. In the sub-Saharan African soil context, could such products be reliable alternative to costly and long-term harmful chemical fertilizers in order to establish and maintain small-scale farming systems?

Mehlich-III P soil test as a predictor of maize yield response to composted cattle manure

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This study evaluated the effect of compost placement on phosphorus (P) availability, and consequently yield, in a maize system during the 2010 and 2011 long rains growing seasons in the Vihiga District of Western Kenya. Compost treatments, applied at the same rate, were (1) broadcast application followed by incorporation, (2) placed in hole below maize seed, (3) banded 3 cm below the surface and 5 cm up-slope of the seed row, and (4) no-compost control. In 2010, compost treatments produced higher yields than the control (α=0.05) at each of the three locations, but there were no differences between compost treatments. In 2011, compost treatments produced higher yields than the control (α=0.05) at two of five locations, but showed no differences at

the other three. At all five locations, there were no differences between compost treatments. A Pearson correlation coefficient was used to determine if there was a relationship between yield and a measurable soil parameter (pH, Bray P-1 and Mehlich-III P) between locations. Mehlich-III P measured in the initial soil samples was positively correlated with yield (α=0.05) while there was no significant correlation between Bray P-1 and yield. A yield response to compost application was observed at locations where the Mehlich-III P was below 15 ppm in the initial soil sample, but no yield response to the addition of compost was observed at locations where the Mehlich-III P was above 15 ppm. This suggests a critical value of around 15 ppm Mehlich-III P for maize in this region.

Fertilité des sols et agriculture urbaine: le cas de l'usage du compost dans l'activité maraîchère

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Au Bénin comme dans la plupart des pays de l'Afrique de l'Ouest, l'agriculture urbaine (AU) est un pilier de l'équilibre alimentaire des centres urbains. En plus de sa valeur nutritionnelles, l'AU et particulièrement le maraîchage est une opportunité d'emploi. L'implication des ONG et des collectivités locales dans la collecte des déchets solides ménagers, ayant conduit à la « valorisation des déchets » dans la ville de Cotonou, a stimulé l'utilisation du compost dans l'activité maraîchère. Cependant, la surexploitation des espaces cultivées, entraine l'appauvrissement des sols souvent constitués de sable meuble, perméable et pauvre en matières organiques. Aussi, la variabilité climatique, traduite, par une augmentation des températures et des survenues constantes de proche de sècheresse augmentent l'évapotranspiration des sols à faible capacités de rétention en eau. Or, la qualité du sol et la disponibilité des ressources en eau sont les premiers atouts qui garantissent la qualité et la quantité de la production maraîchère. L'objectif de cette étude de cas a été d'analyser la perception de l'usage du compost par les producteurs maraîchers de Cotonou. Même si 80% des maraîchers interviewés reconnaissent que le compost est un fertilisant sans impact sur l'environnement, son utilisation reste étroitement lié à son impact sur la quantité de production. Afin d'améliorer les quantités de production, les maraîchers ont adoptés l'utilisation des engrais chimiques qui ont à la fois des impacts négatifs sur l'environnement et sur la qualité des végétaux produits. Face aux fertilisants chimiques qui, tout en réduisant le temps de production augmentent les quantités produites, en plus de leur valeur biologique, le compost offre une alternative durable d'amélioration de la qualité des sols, en augmentant humidité et leur capacité de rétention, qui sont une réponse écologique à la gestion des ressources en eau.

Response of maize to different soil fertility and water harvesting management options in in semi-arid eastern Kenya

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The southern rangelands of semi-arid eastern Kenya are characterized by frequent droughts and crop failures leading to chronic, acute food and nutritional insecurity. In view of the foregoing challenge, the effect of the farmer practice (flat seedbed), tied-ridging and contour furrows water harvesting methods and five integrated soil fertility management options on the performance of rainfed maize was studied on-station in the Kenya Agricultural Research Institute Katumani Research Center during the 2006 and 2007 short rains seasons. The crop was harvested four months later and yields data obtained and analyzed during both seasons. Maize yields responded positively to both water harvesting methods and integrated soil fertility management options. The tied ridging water-harvesting technique had the highest positive effect on performance of maize and final grain yield. The maize also responded positively to a combined application of manure and inorganic fertilizers. Among the integrated soil fertility management options, manure at either 5 or 10 t ha^{-1} plus 20 kg N plus 20 kg P_2O_5 kg ha^{-1} had the most positive effect on performance of and final maize yields. A minimum of manure at 10 t ha^{-1} should be applied on maize plots in the absence of inorganic fertilizers. The tied-ridging water harvesting method could be recommended to farmers in the semi-arid lands.

Scaling up of soybean production among smallholders in Zambia: The case of the MIRACLE project

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The integration of soybean into the continuous maize cropping systems in Zambia has the potential to contribute significantly to food and nutritional security of smallholder farmers, improved soil health, higher crop yields and improved diets. This is especially the case for those that may be affected by HIV and AIDS as is the case with MIRACLE project. Although farmers participating in MIRACLE have consumed soybeans as maize-soy blend through national or international programs, soybeans remain an unpopular crop among most smallholder farmers because soybeans are not traditionally part of a Zambian diet. Although new soybean varieties are being released, smallholder farmers often have limited access to them. In an effort to bridge this gap, MIRACLE project has involved farmers in performance trials of newly released varieties in three different agro-ecological zones of Zambia namely, Kazungula, Mumbwa and Mansa. The agro-ecological zones are divided based on rainfall pattern as the main distinguishing climatic factor. Kazungula is in region 1, receives less than 800 mm of rainfall annually, Mumbwa is in region 2, receives about 800-1000 mm of rainfall annually while Mansa is in region 3 and receives more than 1000 mm of rainfall annually. Data used in this paper are from the field trials that were conducted in the 2011/2012 cropping season, supported by focus group discussions and key informant interviews which comprised of 15-20 male and female participants per site. The objectives of the trials were to test the performance of three varieties of soybean namely, Henon 147-K

and TGX 1740-2F and Lukanga and to test farmer preferences of these soybean varieties. The experimental design was a block of plot size of 10 m x 10 m per variety of soybean on a 'mother' trial plot and this was replicated twice by two farmers on 'baby' trial plots in different locations within the different agro-ecological zones. Each variety of soybean had "control" plot and these did not have any treatments while the treatment plots had, fertilizer, lime and inoculum. Conservation Agriculture methods of basins or ripping were used in all the plots using ripping or pot holing. Where ripping methods was used, seeds were drilled at a spacing of 3.5 cm and spacing in between rows was 50 cm. Where pot holing method was used, each pot hole was planted with 12-14 seeds and spacing in between pot holes was 45 cm. Glyphosate was used to control weeds at a rate of 2.5 l/ha immediately after seeding. Manual weeding was done twice at 4 weeks interval. Results of the trials indicate that those treatments including rhizobial inoculation of soybean, liming and application of phosphorus fertilizers increased yields substantially over zero treatments. Farmers preferred early maturing soybean varieties with a large grain size. However, soybean was ranked as the least preferred legume particularly by women groups. The reasons for this being included soybean being a new crop with little knowledge about processing, utilization, or marketing as well as non-availability of seed. This confirms the results from other studies that increasing production of promoted crop varieties, require seed to be readily available, market linkages to be developed, training to be provided on utilization and processing, as well as local preferences to be taken into account.

Biochar alters plant growth and N fixation of common bean in western Kenya

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Biological nitrogen fixation (BNF) in legumes is an integral component of crop production in smallholder systems of sub-Saharan Africa. Increasing the synergies in the plant-microbe symbiosis could simultaneously improve food security and soil fertility through greater legume grain yields and biologically fixed N. Recent studies have documented increased BNF and grain yield in common beans (*Phaseolus vulgaris*) following biochar (charcoal) application to soil in the Amazon. However, the mechanism for this response remains unknown as does whether these results vary by biochar feedstock or production conditions. Further, the relative composition of biochar, e.g., free mineral nutrients, ash content (liming potential), and volatile matter vary with by feedstock and production conditions, which may also contribute to observed responses. A greenhouse experiment was undertaken to isolate the individual components of the biochar and to test their effects on BNF when contrasting feedstocks and production temperatures are used. Biochar was manufactured from feedstocks available in western Kenya. The feedstocks were sugarcane bagasse, rice hulls, maize stover, maize cobs, eucalyptus wood (*Eucalyptus saligna*), *Delonix regia* wood, and tea bush (*Camilia sinensis*) prunings. These feedstocks were pyrolyzed at 350 or 550˚C. Each feedstock and temperature combination was treated with either steam to remove both the minerals and the volatile matter, HCl (adjusted back to the original pH) to remove the minerals, or acetone to remove the volatile matterand compared to unaltered biochar. The biochars were added to a highly degraded oxisol from western Kenya at the equivalent rate of 15 t ha^{-1}. Nodulating and non-nodulating isolines of the common bean variety DOR 364 were grown in pots. In soils amended with biochar, plant biomass production increased by 289%, nodulation increased by 780%, nodule biomass increased by 48-fold, tissue N concentration increased by 186%, and BNF increased 12-fold. There were significant differences in all of these metrics between feedstocks. Among the feedstocks, rice hull biochar had the greatest positive responses. There were no consistent trends between production temperatures, however, BNF was higher when biochar was produced at 550˚C as compared to 350˚C. Most metrics were increased significantly in soils receiving acetone-treated biochar compared to steam-treated, HCl-treated, or raw biochar. Final analyses are underway to relate biochar properties to plant responses and to isolate the potential biophysical mechanisms underlying observed responses.

Residual effects of organic soil inputs of contrasting quality on maize yield in the highlands of western Kenya

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Soil fertility is the main biophysical constraint to crop productivity in Sub-Saharan Africa. Lack of affordable mineral fertilizers and intensive farming has resulted in widespread loss of soil nutrients and a corresponding loss of soil organic matter. Soils depleted of organic matter often respond poorly to mineral fertilizers and are less resilient to global climate change. The residual effects of organic inputs of contrasting quality on maize productivity were investigated as a function of soil degradation in the highlands of western Kenya. Tithonia (*Tithonia diversifolia* (Hemsl.) A. Gray) green manure, cypress sawdust, and biochar made from eucalyptus wood were applied at a rate of 6 t C ha^{-1} for three cropping seasons, both with and without mineral fertilizer additions (120 kg N ha^{-1}, 100 kg K ha^{-1}, 100 kg P ha^{-1}). Maize grain yield was monitored for four years beyond the initial organic matter additions. The greatest yield responses for all amendments were found on the most degraded soil. During those years when amendments were added, tithonia applications resulted in the greatest yield increases, between 153 and 183% more than the unamended control in comparison to 136% with biochar and 107% with sawdust additions. However, four years after tithonia applications to highly degraded soils stopped, yields rapidly declined to only 110% of the unamended control, whereas yields after biochar additions remained constant at 0.3-1.8 t yr^{-1} or 9-265% greater than yields without organic amendments. Four years after organic matter additions ended, maize yields were not significantly different irrespective of additions of the quality of organic amendments. Even four years after organic matter additions, yields in response to fertilizer additions to highly degraded soils were 113% greater when applied together with the organic inputs than alone. Whether as a result of immediate or residual effects, no significant differences were found with or without fertilizer or organic matter additions in the farms recently converted from forest. The data indicate that yield responds in the short-term to input quality and specifically the amount of applied N while the residual effects of organic matter additions on yield dynamics may relate more to input C quality and increasing soil C.

Response of *Eragrostis tef* to zinc fertilization on Vertisols in Ethiopia

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Zinc deficiency is common in plants, animals and humans in developing countries where soil Zn supply is limited. It is considered the most widespread micronutrient deficiency in cereals, causing reduction in yield and quality. Recently a decline in response to N and P fertilizers was observed on Ethiopian Vertisols and it was hypothesized that Zn could have become a growth-limiting factor. A series of field and greenhouse experiments in 2007-2010 were implemented to determine and understand the response of teff (*Eragrostis tef* (Zucc.) Trotter) to Zn. Teff is a major staple food crop in Ethiopia and Eritrea. Increasing the grain Zn concentration would be beneficial for the Zn deficient consumers. The results demonstrated that i) Zn deficiency is a critical nutritional problem on Vertisols in Ethiopia that limits teff production, and 8 kg Zn ha^{-1} is sufficient to correct the deficiency, ii) Zn fertilizer improved both grain and straw Zn concentration of teff under greenhouse conditions but not under field conditions, iii) grain Zn concentration of teff varied with the varieties and Zn application under greenhouse and vi) after teff crop was harvested, only Zn rates above the sufficient Zn rate (8 kg Zn ha^{-1}) have soil Zn availability above the soil critical limit (DTPA-Zn, 1 mg kg^{-1} soil). It was concluded that Zn fertilization can increase yield of teff in high pH Vertisols in Ethiopia but may not be a promising strategy to increase Zn density in teff grain. A future research strategy to enrich teff grain with Zn could be to test teff varieties in response to Zn fertilizer under field condition, genetic bio-fortification, or mycorrhizal inoculation.

Diversity of arbuscular mycorrhizal fungi associated with potato in Morocco

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Arbuscular mycorrhizal (AM) association helps plant growth and improves crop production. The response of arbuscular mycorrhizal plants grown under varying nutrient regimes has been characterized. At that time, differences in plant development caused by different nutrient treatments were related to mycorrhizal colonization levels, which increased for low-nutrient seedlings and decreased in high-nutrient seedlings. Few data are available concerning potato plants and arbuscular mycorrhizal fungi (AMF). The influence of AMF species on potato reponse to P nutrition and the effect on tuber yield and size or on productivity have been analyzed previously. However, to our knowledge, no data are available about the behaviour of AMF associated to potato crop under gradient sterss nutrient of (N,P,K). Our study aims to understand the impact of different fertilization treatments (N,P,K) on soil organic matter, available soil nutrients, mycorrhizal properties as well as on the yield response, tuber size of potato crop. The study was carried out in experimental station of Regional Center of Agriculture Research in Larache in Morocco. Doses of N, P, K were fractionated according to the cycle of culture. Soil samples were collected at two depths: 0-20 and 20-40 cm. The pH, total carbon (C), organic matter (Mo), nitrogen (N), Phosphorus (P) and Potassium (K), spore of(AMF) density in each sampling point as well as leaf area, height of the stem, yield and size of tuber was determined for each plot. The statistical analysis has shown a significant difference in growth and yield parameters between different treatments. In fertilized plot, growth and yield (65T/ha) parameters were higher than in the unfertilized control (40T/ha).The analysis also has shown a high level of spores (CMA) at sampling depth 0-20 cm (2500/100 g dry soil) relative to sampling depth 20-40cm (1750/100 g of dry soil).the statistical analysis has revealed an abundance of *Gigaspora* relative to *Glomus.* These results show that management of soil fertility significantly affects soil microbial diversity in addition to their chemical quality and/or physicochemical. Management inputs of N, P, K also improves soil fertility, the crop yield and exportable tuber size, this improvement also depends on the sequence agronomic or rotation.

Biochar effects on arbuscular mycorrhizal fungi

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Biochar is a carbon rich and slowly degradable soil amendment, derived from pyrolysed biomass. Biochar addition has been shown to improve plant growth in many different soils, but direct effects on arbuscular mycorrhizal fungi (AMF) are much less known. We found that biochar is an attractive habitat for the external mycelium of AMF, both in soil systems and also without the presence of other microorganisms in sterile cultures.We also found that biochar can ameliorate salinity problems in soils, presumably by immobilizing parts of the toxic salt ions. In a greenhouse experiment, we investigated the interactions of biochar addition, mycorrhizal inoculation and elevated salinity on performance of salad plants. Salinity decreased biomass drastically, but this effect was ameliorated if biochar or AMF were present.One and a half year ago, on the first Afrinom- meeting in Dakar, we started a Pan-african experiment on the effects of biochar on the external mycelium of AMF, repeated in many African countries. I also want to present the first results from this experiment.

"Intensificationability": the potential to intensify for households growing rainfed crops on small farms

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Agricultural technologies are developed with the primary objective of increasing yield but household decisions to adopt technologies are heavily influenced by the likely return on investment (of money, labour, etc.). If crop production is not the only source of household income, the opportunity cost of adoption is also a factor in decision making. The profitability (in its broadest sense) of rainfed crop production is considered in the context of smallholder household resource availability, in particular farm size. The amount of land required to provide any household target income (e.g. $1/person/day) depends only on the net return – benefits minus variable costs including labour - ($/hectare/season) and the number of people in the household. Using this relationship, the potential contribution of rainfed crop production to household income is explored. Similarly, this analytical approach can be used to characterise sites with regard to rural communities' ability to benefit from agricultural intensification.

Selection of phosphate solubilising plant growth promoting microorganisms for use in Cameroon

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African soils are deficient in phosphate and limited fertilizer use has driven interest in native phosphate solubilising microorganisms to improve productivity. We demonstrate preliminary isolation, characterization and function of microorganisms isolated from Cameroonian soils. Soils from 5 agroecological zones of Cameroon were used to assess microbial community structure by T-RFLP and isolate phosphate solubilising microorganisms. The activity of isolates was tested and identification of efficient strains was made. Selected isolates were inoculated onto soil grown plants and performance with various insoluble phosphates was measured. 336 phosphate solubilising isolates were obtained. 168 bacteria and 66 fungi were sequenced representing 8 fungal and 10 bacterial taxa. *Cladosporium* and *Burkholderia* were found in the wettest regions, while *Aspergillus* and *Bacillus* were found in all zones. Isolates displayed differential P solubilising activity and when inoculated onto plants, between 10 and 40% increases in P-accumulation and biomass of plants were observed. P-solubilising microorganisms can be isolated from all agro-ecological zones of Cameroon and these isolates are capable of promoting plant growth in controlled conditions. Once confirmed under field conditions, these results allow the development of tailored microbial solutions to P-deficiency issues in sub-Saharan Africa.

Nitrogen retention during composting with biochar

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Compost is a valuable soil amendment that can be locally produced and used by smallholders worldwide. Compost can confer many benefits to agricultural systems, but nitrogen (N) loss during composting can be substantial, resulting in air pollution and reduced nutrient value of the compost. Previous studies have shown that biochar additions to compost influence N cycling and reduce gaseous N loss from compost. However, little is known about biochar-compost interactions and the mechanisms responsible for improved N retention. We investigated the effect of biochar characteristics on its capacity to reduce ammonia (NH_3) loss from compost. Our hypothesis was that the biochar's capacity to reduce NH_3 volatilization was largely dependent on the acidic functionality of the biochar's surfaces. A range of biochars with varying acidic functionality were produced. The sorption capacity of each biochar was evaluated using ammonium adsorption isotherms. Subsequently, the biochars were added to batches of compost feedstock and placed in bioreactors. The different compost-biochar mixtures were monitored for moisture, temperature, pH, gas emission, mass loss, and C/N content. The results from this experiment can be used to optimize biochar characteristics for compost production and improve N use efficiency in agricultural systems. By using biochar to improve N retention in compost, farmers can improve N delivery to crops without increasing their dependence on synthetic fertilizers.

Nutrient uptake potential of selected under-utilized vegetables of Southwestern Nigeria

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Improved production and consumption of under-utilized vegetables could reduce poor nutrition, hunger and adverse effect of climate change on people in developing countries. This study investigates the nutrient uptake potential of ten under-utilized vegetables grown on different soil types with the view to evaluate their nutrient use efficiency and nutritional quality. The ten vegetable crops were African snake tomato (*Trichosanthes cucum*erina L.), Ebolo (*Crassocephalum crepidoides* L), local Amaranth (*Amaranthus viridis* L), Woorowo (*Solanecio biafrae*), Bitter leaf (*Vernonia amygdalina* Del.), Ogunmo (*Solanum* spp), Gbagba, Elegede, Fluted pumpkin (*Telfairea occidentalis*) and Odu. Both the effects of stem cutting sizes on *S. biafrae* and *V. amygdalina* (which are vegetatively propagated) and the use of seed density were investigated on other vegetables. The study was conducted on volunteer farmers' plots in the savannah and forest zones of Osun, Oyo, Ondo and Ekiti states of Nigeria between April and August, 2012. Composted organic manure and urea were applied to supply 40 kg N ha^{-1}. The soil pH, organic matter content, total N, exchangeable cations and available P were evaluated before and after cultivation. The vegetables were

harvested by cutting four times viz: 6, 8, 10, 12 weeks after planting. The dry matter yield and the nutrient contents of the vegetables were also be determined from which the nutrient uptake of each harvested vegetable were estimated. Preliminary results show significant effect of spacing on the performance and nutrient composition and the food value of the vegetables. These under-utilized vegetables promise higher nutritional potentials compared with more widely cultivated vegetables.

Nutrient management practices for vegetable production in semi-arid Eastern Kenya

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Declining soil fertility is one of the major factors contributing to the current low productivity of crops in the crop-livestock production systems in the semi-arid areas of Kenya. This study was conducted in the peri-urban areas of Machakos and Wote towns in semi-arid Eastern Kenya with the aim of identifying nutrient management practices currently used in the smallholder crop-livestock production systems and to develop appropriate nutrient management strategies for enhancing the productivity of vegetables. The survey covered 15 km radius around the urban centres and the target population consisted of smallholder farmers owning at least one dairy cow. In the peri-urban areas of Machakos town, a total of 60 farmers were interviewed while in the peri-urban areas of Wote town, 56 farmers were interviewed using structured questionnaires between February and July 2010. The two major vegetables grown in the two areas were kale and tomatoes. Farmyard manure, particularly cattle manure, was the principal source of nutrients for vegetable production. In both areas, a majority of farmers heaped their manure without covering it and applied it, mostly in furrows and pits, every season. It was concluded that emphasis should be focused on promotion of adapted feed resources that increase milk production and improve soil fertility strategies that mitigate nutrient losses during handling and storage of manure and sensitizing farmers on the use of organic sources of nutrients other than farmyard manure and compost in combination with inorganic sources in order to optimize all aspects of nutrient cycling.

Virus infections: The major constraint for the productivity of tropical commercial grain legumes in symbiosis with rhizobia

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Virus infections constitute a constraint that is more important than salinity, acidity, high temperatures and drought for the productivity of all commercial grain legumes in tropical areas. Each grain legume species is susceptible to infection by at least 5 different viruses and currently there are no commercial varieties available to farmers with resistance to any virus infections. The most common situation in the field is the spread of the virus particles by insects and nematodes. In this case, the virus infection takes place after occurrence of the first events of symbiosis with rhizobium. Once inside leaves, the virus particles move rapidly toward the nodules via plasmodesmata, where they massively replicate, form crystalline virus inclusion bodies and cause severe alteration in the ultrastructure of symbiosomes, which affect negatively the rates of N_2-fixation and growth of the plants. On the other hand, the transmission of virus by seeds is the nightmare of farmers since this mode of infection insures the presence and spread of the virus in the crop, hindering even further the nodulation and growth of the plants. Those drastic effects are due to virus-induced malformation in the morphology of the root hairs, which hampers the attachment of rhizobia and, hence, formation of nodules. This situation enforces the urgent need to provide farmers with virus-free-certified legume seeds. The cases of the southern bean mosaic sobemovirus, cowpea chlorotic mottle bromovirus and cowpea mild mottle carlavirus that infect black bean, yardlong bean, mungbean and cowpea will be discussed in detail.

Indigenous arbuscular mycorrhizal fungi associated with rhizosphere of cowpea in Benin

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Research was carried out to assess the biological diversity of indigenous arbuscular mycorrhizal fungi (AMF) species associated with cowpea (*Vigna unguiculata* L. Walp.) in different agroecological zones of Benin. The effects of soil physical and chemical characteristics, climatic factors and agricultural practices on the distribution and diversity of arbuscular mycorrhizal fungal spores was investigated. Then, twenty-eight farmers' fields located in seven agroecological zones of Benin were grown with cowpea. Soils sampling was done at sowing, flowering and harvest followed by a short survey on the story of the cropping systems occurring in the different farmers' fields. Results indicated that cowpea was grown by farmers in very exhausted soil, where available phosphorus and potassium were deficient. The indigenous AM spores were the same for all agroecological systems and the average spores' density was 202 spores per 100 g dry soil. Fifteen AMF species belonging to four genera (*Gigaspora, Scutellospora, Acaulospora* and *Glomus*) were trapped. The diversity of the AMF community was weak with prevalence of the genera *Glomus* (95%). Furthermore, AMF diversity and evenness indices were negatively correlated with annual rainfall ($P<0.01$) and with available phosphorus ($P<0.05$). However, no significant correlation was observed between AMF diversity indices and soil organic matter. Further studies are needed to determine the functionally active AMF associated with cowpea.

Improving productivity of millet- and sorghum-based systems in Northern Nigeria

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Crop production systems in the semi-arid Sudan savanna of Nigeria are mostly rain-fed, predominantly millet- and sorghum-based and often intercropped with legumes. The systems have remained largely subsistent, characterized by low yields and high post harvest losses due to the inherently poor soils, inter- and intra- seasonal droughts, and lack of adequate access to inputs and output markets. Addressing the multitude of problems affecting the resource-poor farmer in the region requires an integrated approach. In 2010 the Alliance for Green Revolution in Africa (AGRA) funded a 3-year project to promote integrated soil fertility management (ISFM) practices in Kano State, within the Nigerian Sudan savanna region. The technologies assessed on 150 lead farmers' fields in 30 communities included cereal/legume rotations using improved germplasm and the use of recommended fertilizer practices on the component crops. The study assessed the rotation benefits of millet or sorghum intercropped with cowpea, soybean or groundnut in a 4:4 cereal/legume strip cropping pattern. The results showed that there were clear benefits in the strip intercrop combinations involving improved cultivars compared to the traditional mixed intercrop involving farmers' local cultivars. Millet cultivar SOSAT C-88 intercropped with cowpea cultivar IT90K-277-2 gave 124% increase in millet grain yield whereas local millet intercropped with local groundnut resulted in benefit of only 8%. The results also showed rotation benefits for sorghum cultivar CSR-01 intercropped with groundnut cultivars SAMNUT22, SAMNUT23 and cowpea cultivar IT90K-277-2 with yield increases of 125%, 74% and 40%, respectively compared to local sorghum intercropped with local cowpea, soybean or groundnut which gave benefits of between 7% to 15% only. The cost and return analysis indicated the profitability and return per Naira invested was higher in the combination of the improved cultivars over farmers' variety and practice. The most profitable combinations were SOSAT C-88 intercropped with SAMNUT 22 in the millet based systems and CSR-01 intercropped with soybean cultivar TGX1448-2E, cowpea cultivar IT90K-277-2 or groundnut SAMNUT23 in the sorghum based systems. The improved intercropping system of 4:4 cereal-legume strip cropping system produced higher yields and net returns than the farmers' traditional mixed intercrop.

Building fertilizer recommendations to support ISFM

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There is a growing awareness of the role that fertilizers play in building sustainable and profitable food security in Africa. Fertilizers are but one of the building blocks leading to improved crop productivity. The International Plant Nutrition Institute (IPNI) has developed a decision support system (DSS) tool which provides a scientific basis for making fertilizer recommendations in the absence of soil testing, a challenging obstacle for most smallholder farmers in Africa and Asia. The tool has been named Nutrient Expert, and to date is being used to make maize and wheat fertilizer recommendations. While the science behind the nutrients required to increase yields is the Quefts model, the DSS incorporates regional science and local "expert knowledge" to adjust recommendations to the site-specific field. In field management such as crop residue retention, legume crop management, previous crop yield, prior fertilizer and manure use and supplemental water supply are just a few of the factors which can be adjusted in making a recommendation. More importantly, the DSS model also allows for recommendations to be made based on the farmer setting their specific yield goal, which can vary significantly from field to field, and farm to farm. Finally the output from the DSS tool also allows for variation in long-term rainfall patterns to change the actual recommendation, preventing investment for in-season fertilizer application when the potential for capturing the benefits are low. Examples of how the model has been adapted to South Asia and China will be presented to support the robust potential of this recommendation DSS tool. Future food security of smallholder farming systems is dependent on fertilizer recommendations which consider the yield goals of the farmer and the replacement of fertilizer with other organic resources. We believe that DSS tools like Nutrient Expert can play an important role in helping this effort.

Embracing the market led approach to drive the ISFM agenda: lessons from working with Soybean Resource Centers in Western Kenya

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Integrated Soil Fertility Management (ISFM) is defined in the spheres of fertility management practices (use of inorganic and inorganic fertilizers), improved crop varieties combined with knowledge on how to adapt these practices to local conditions aiming to maximize agronomic use efficiency of the applied nutrients and thus crop productivity. Legumes have a high potential of improving soil fertility through their ability to change the inert atmospheric nitrogen into usable form through a process known as Biological Nitrogen Fixation (BNF). Important legumes like soybean with a high BNF potential have not been fully embraced by the farmers, their benefits in the soils notwithstanding. The adoption of soybeans has been hampered by many factors including limited knowledge on processing and marketing constrains. This paper provides the lessons learnt from working with the soybean resource centers (SRCs) established Western Kenya which are involved in collective soybean marketing and value addition. The constrains to soybean production and intervention measures are explored and the gains made in marketing linkage discussed. Before the establishment of the soybean resource centers in 2005, less than 40 ha of land was under soybean production, with an average annual yield of 20 T and a soybean farming population of slightly above 300 farmers. With the establishment of the centers, the land size under soybean production has increased to over 400 ha, the soybean

productivity ha^{-1} has increased from 600 kg to 2.5 t ha^{-1} and the soybean farming population increased to over 5000 farmers. The total number of farmers trained to date on soybean value addition stands at 4,201.

Symbiotic effectiveness of rhizobia in smallholder soyabean production in Zimbabwe

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Poor nodulation due to low native rhizobial populations has been observed in smallholder farms and has resulted in low soyabean productivity, leaving farmers in need of effective strains to increase nodulation and productivity. In this study agronomic trials were carried out in Mudzi (Natural Region IV), Murewa (Natural Region II) and Mhondoro (Natural Region III) to evaluate responses of selected promiscuous and specific soyabean varieties to seed inoculation with selected indigenous and exotic rhizobial strains. The strains tested were MAR1305, MAR1306, MAR1326, MAR1491, MAR1494, MAR1497 and MAR1515 from the Grasslands Research collection. Highest biomass yields were attained with MAR1305 in Mhondoro and Murewa with yields of 960 kg/ha and 2627 kg/ha respectively. MAR1515 yielded lowest in Murewa (1840 kg/ha) with MAR1497 (560 kg/ha) and MAR1305 (431 kg/ha) yielding lowest in Mhondoro and Mudzi respectively. Significant differences among strains were recorded in Murewa and Mhondoro ($p<0.011$ and $p<0.015$ respectively) while in Mudzi all the strains did not show significant differences. In all sites the promiscuous varieties yielded higher than specific varieties. There were significant differences between nodule scores of all strains in all districts ($p<0.002$) with MAR1305, MAR1306 and MAR1326 having the most effective nodules. Preliminary results for all districts for grain yield show yields ranging from 0.2 t/ha- 2.9 t/ha. In conclusion soyabean varieties must be matched to strains and recommendations to farmers should clarify that not all rhizobia will nodulate in all soil types.

Maize response to application of inorganic fertilizers, and manure in eastern and northern Uganda

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Maize (*Zea mays* L.) is important for smallholder production in Uganda. Grain yields are low because of low soil fertility and little fertilizer use. Yield response to alternative soil fertility management strategies were evaluated by farmers in eastern Uganda. Farmer managed on-farm demonstrations were conducted in Mid Northern, Lake Victoria Crescent and Southern and Eastern Lake Kyoga Basin of eastern Uganda at an altitude of 1050 masl. There was a significant ($P < 5\%$) increase in maize grain yield in response to application of kraal manure, combination of kraal manure with inorganic N and P, and inorganic N, P and K fertilizers compared to the control and between the different strategies. This clearly indicate that low soil fertility is a constraint to maize production in Uganda and the use of alternative strategies will result in increased crop yield hence food and income security. The benefit/cost ratio of the different strategies were 1.07, 1.30, 1.10 and 0.88 for manure, a combination of manure and inorganic NP fertilizers, inorganic NP fertilizers, respectively, indicating that farmers get back the investment made for the alternative strategies, however application of NPK is not profitable despite the significant increase in yield which does not cover the extra investment in K fertilizers. The reduction in the B/C with application of inorganic fertilizers is due to the high cost of inorganic fertilizers, to low farm gate price of grain ratio (C:P). Reduction in the C:P ratio will require intervention at policy levels.

Long-term productivity of maize and pigeon pea cropping systems in Malawi

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In a recent study of cropping systems in Malawi, mineral nitrogen (N) additions reduce soil nutrient balance and sustainability of soil quality and crop yield in maize/pigeonpea intercropping systems. Three cropping systems commonly practised in Malawi were evaluated for their sustainability of soil quality and maize yields. The sustainability of three cropping systems (maize monocropping, maize/pigeonpea intercropping and maize-pigeonpea crop rotation) was measured using the nutrient balance technique. Two levels of mineral N applications, 0 and 65 kg N ha^{-1}were applied. Treatments were laid out in a Randomised Complete Block in a split-split design with three replications. Additions of mineral N increased maize grain yields in the short term. In the long term, mineral N addition reduced soil nutrient balance, sustainability of soil quality and increased interspecies competition in the maize/pigeonpea row-intercropping system. Negative nutrient balances were more pronounced in maize monocropping system while positive nutrient balances were pronounced in cropping systems where long duration pigeonpea was included as an intercrop or in rotation with no addition of mineral N fertilizer.

Effect of long-term fertilizer application on striga density

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The study to assess the effect of 7 year fertilizer application on the density of striga was conducted, on-farm in 12 farms at 3 sites (Emusutswe, Nyabeda and Nyalgunga) in Western Kenya. The hypothesis was that continual fertilizer application would

improve soil fertility and hence decrease the occurrence of the parasitic weed. A split-plot design in randomized blocks with 4 replicates per site was used were the main plots were the soil fertility levels and the split plots were the treatments. 5 treatments for improving soil fertility were applied namely: local maize (DH04) control; IR maize (WS303) control; IR maize + FYM; IR maize+ Mavuno and IR maize +FYM +mavuno. FYM was applied at a rate of 60 kg N/ha and mavuno at a rate of 20kg P/ha. There were significant differences between treatments ($P<0.001$) with the highest striga density observed in local maize control treatment (mean=41,367plants/ha). and lowest striga density observed in IR+man+mav treatments (mean= 8437 plants/ha). There were significant differences observed between IR maize and local maize controls with mean striga density = 18,843 plants/ha for the IR maize control treatment. Treatments IR+manure and IR+mavuno were not significantly different. No significant differences were observed between fertility levels (high and low). The highest striga density was observed in local maize control treatment. A combination of FYM and mavuno can therefore help in the reduction in striga occurrence.

Characterizing markets for soil fertility and land management in the grain basket areas of Kenya

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The fertility status of most soils in sub-Saharan Africa has been declining over time such that very few areas can adequately support crop production without supplementary nutrients or other soil amendments. Integrated Soil Fertility Management (ISFM) includes the combined use of soil amendments, organic materials, and mineral fertilizers and is recommended to replenish soil nutrients, improve soil structure and the efficiency in use of external inputs. Towards this effort, numerous soil fertility amendments or land management techniques are available for farmers to use. These range from mineral fertilizers, organic or green manures, leguminous crops, bio-fixing organisms, agro-forestry, terracing, grass strips, among others. Although various efforts have been put into dissemination of the various techniques, low demand for and poorly developed markets for ISFM (other than inorganic fertilizers) are often cited as the reasons for their poor uptake. Outside mineral fertilizers, little is known about the structure of the market for and the level of demand for technologies/innovations included in the ISFM menu. This greatly challenges the targeting not only of innovations in soil fertility management but also public and private investments. This paper seeks to characterize the market and assess demand for soil fertility management and land management techniques. The results will help in targeting fertility and land management innovations for greater adoption and impact.We use multivariate probit and double hurdle models to estimate farmer demand for inorganic, organic and other soil amendments, controlling for plot, household and market characteristics. The analysis is based on plot-level data collected in 2008/9 from 1001 households in eight agro-ecological zones in western and central Kenya.

Application of cluster techniques for soil fertility trial site selection and characterization in Eastern Kenya

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This work was carried out in Kiboko District, Makueni County in Eastern Kenya by a global project which aims at assessing and promoting nutrient management practices that optimize and improve maize productivity. Site selection was conducted between 6th and 13th March, 2012. Soils within study sites areas can be described as well drained, very deep to moderately deep, dusky red to red and dark red to dark brown, friable clays, with a sandy over-wash topsoil. A Land Degradation Surveillance Framework (LDSF) protocol was used to select study sites using a 10m x 10 m grid-based hierarchical sampling matrix design. From the grid, 16 clusters measuring 2.5 km2 were established, from where random coordinates were generated around a central point. Each cluster point had about 15 possible farms/sample points. The cluster and sampling points were then coded and downloaded into a GPS unit. From each cluster, two farms were selected guided by the GPS (Global Position System device), levelness of the sites and willingness of the farmer to give out his/her farm for 5 seasons. Based on this criterion, farms were selected from smallholder cropping landscapes and from institutions such as secondary schools. Thirty farms (sites) were selected from which composite soil fertility samples were collected using the LDSF- "Y sampling frame". Subsequent nutrient analysis was conducted at the KARI Kabete Laboratories. A study site thematic map was then generated embedded with the area road networks from routes captured by the GPS unit. The purpose of the analysis was to get baseline fertility levels of the sites before starting experimentation.Soil sampling was conducted to a 20-cm depth using a soil auger. Out of the 30 selected sites, eighty one percent of the sites had a pH of 6.5-7.0, all other sites had a pH greater than or equal to 6.0. All sites were deficient in total nitrogen (< 0.2%). Ninety six percent of the sites had low levels of total organic carbon (<1.33% OC). Ninety four percent of the sites had excessive levels of phosphorus (> 80 ppm Mehlich or Olsen P). Ninety six percent of the sites had adequate levels of potassium (>0.24-1.50 me %). Seventy three percent of the sites had adequate levels of calcium (2.0-15 me %). Ninety seven percent of the sites had excessive levels of magnesium (> 3.0 me %). All sites had adequate levels of manganese and copper. Ninety six percent of the sites had adequate levels of iron (> 10 me %). Eight five percent of the sites were deficient in zinc (< 5.0 ppm). Good responses can be expected by application of nitrogen containing fertilizers, manure and trace elements like zinc.

Establishment of a promotional program for biological depollution of arable lands in Mali

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The present study is about the evaluation of the biological breakdown of the plant health products, the chemical compounds and heavy metals in five (5) samples of soils taken from the fields of cotton, rice and cereals of CMDT and the Office zone of Niger. The residues of pesticides were analyzed by gas chromatography after extraction and purification. The analyses revealed a contamination of the soils by the varying atrazine from 0.009 to 0.01 mg/kg, by the carbofuran and the varying endosulfan from 0.005 to 0.008 mg/kg. We notice the presence of eight (8) heavy metals (Ac, Cd, Pb, Al, Fe, Zn, Cr, Co) in all the samples of soils. The strong concentrations of Fe and Zn do not constitute pollution, but they are of geological origin. A pollution by Cd was observed: its concentration is 1.3 times (soil 4) and 1.5 times higher than the European standard (soil 2 and soil 5). The follow-up at the laboratory of the degradation of the pesticides in various types of soils showed that this degradation is faster in the soils rich in organic matter and clay. The degradation of biocides and heavy metals by the bacterial communities can be influenced by environmental factors such as the pH, the temperature and the content of nutrients.

Bio-fortified bean genotypes under integrated soil fertility management in DR Congo

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Bio-fortified bean, from their genetic variability and their potential to import micronutrients from soil such as iron and zinc in addition to protein, are an appropriate alternative to improve nutrition status of rural vulnerable populations. Eight bush genotypes were planted with eight integrated soil fertility, with aim to evaluate their performance in terms of yield, micronutrients content and pest and diseases severity. Eight locations representing main agro-ecologies in South Kivu, North Kivu and Katanga in DRC were selected for this trial and repeated 3 years from 2009 to 2011. The split-plot design was used with eight bean varieties as main plots and eight options of integrated soil fertility management as secondary plot. Soil samples were collected before planting and after harvest as well as sample of seed from each plot were analyzed. Results showed that there was high significant differences ($P<0.001$) between genotypes, locations and year both for yield, iron and zinc. Even all interactions were highly significant. The combination of farm manure, lime and mineral fertilizer increased yield up to 87.3% , iron up to 21.7% , zinc up to 11.8 % and reduced severity of root rots by 17.8% , angular leaf spots with 15.3% and bean steam maggot with 17.4% , but this influence was variable and depending more on soil conditions than climatic patterns. In some locations, genotypes did not show any response to lime.

Organic versus conventional farming: maize and baby corn yields in Central Kenya

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Crop productivity is declining in the high potential areas of Kenya due to fast deteriorating natural resource base, climate change, large post-harvest losses, low extension coverage, unaffordable mineral fertilizers and diminishing land holdings. Unlike Kenya, agriculture in the northern hemisphere is dominated by large-scale farming, which relies heavily on synthetic inputs to sustain high yields. Prolonged injudicious usage however can be detrimental to human health and environment hence renewed interest in organic farming. Comparative studies in the north have proven that organic agriculture is superior to conventional agriculture in ecosystem services delivery and economic viability, and probably has potential to make yields more stable in risk-prone tropical environments. However, disparities in soils, socio-economic environments and climate hinder direct transfer of technologies from the cold northern to the warmer countries in the southern hemisphere hence the need for comparative studies in the tropical environments. With a hypothesis that organic farming is more sustainable than conventional farming, the 'Long-term Farming Systems Comparisons in the Tropics Project' has been comparing organic versus conventional farming systems in relation to quality and quantity of crop products, resource use efficiencies and sustainability of the agro-ecological system at two sites in Kenya (Chuka and KARI-Thika sites). The objective is to provide solid agronomic, environmental and social economic data on inputs at commercial and local farmer input levels and to disseminating these findings to stakeholders. The trial features a three-year maize-based rotation system in which horticultural crops are incorporated. The Chuka site has four treatments; Conventional High [CH], Conventional Low [CL], Organic High [OH] and Organic Low [OL] imposed in 8m x 8m plots and replicated four times in a Randomized Complete Block Design (RCBD). Nutrients in the Conventional treatments are supplied by farmyard manure, diammonium phosphate and calcium ammonium nitrate while compost, *Tithonia diversifolia*, and rock phosphate supply nutrients in the Organic treatments. Pests are controlled using biopesticides in Organic treatments and synthetic pesticides in Conventional treatments. In 2007, maize grain yields in CH (4.9 t/ha) and OH (4.5 t/ha) were comparable while OL (3.7 t/ha) out performed CL (2.5t/ha). In 2008, babycorn yields in OH (3.9 t/ha) were significantly higher than CH (2.8 t/ha) while maize grain yields were similar in the low treatments (CL 2.3 t/ha; OL 2 t/ha). These preliminary results show promise for the organic system in the high potential areas of Kenya.

Soil salinization in selected irrigation schemes in semi-arid lands of Kenya

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A study was carried out in five irrigation schemes in Taveta County to investigate the extent of soil salinization to develop an effective management strategy for increased crop production and food security in irrigation schemes where crop productivity is declining due to soil salinity encroachment. The research involved sampling irrigation waters and soil from the sources and the irrigation schemes, respectively. Water analysis showed that irrigation water from Kasokoni (1119.9 µS/cm and [Na] of 3.92 me/l), Rama springs (1363.75 µS/cm and [Na] of 5.75 me/l) and Kimala canal (1328.67 µS/cm and [Na] of 4.59 me/l) were significantly ($p \leq 0.05$) saline. Water from Njukini (279.2 µS/cm and [Na] of 0.66 me/l), Challa (386 µS/cm and [Na] of 1.16 me/l), Njoro Kubwa (244.4 µS/cm and [Na] of 0.632 me/l), Grogan springs(377 µS/cm and [Na] of 0.73 me/l.) and Lumi springs (207 µS/cm and [Na] of 0.387 me/l) before joining Kasokoni springs were not saline. Kamleza-Kimoringo soils irrigated with water from Njoro Kubwa, of low salinity, were found to be significantly ($p \leq 0.05$) more saline (Ece 1.66 mS/cm) than other soils from other schemes whose Ece were generally below 0.56 mS/cm. These soils were at the lowest part of the irrigation schemes near lake Jipe, had a clay texture (48.74 % clay, 27.26 % silt and 23.68 % sand), significantly ($p \leq 0.05$) more soluble salts (mean Ca 2+ 20.968 me/100g soil). Soil pH, Ece, [Na+] ,[Ca2+] did not vary with soil depth. It was concluded that the salts could have been deposited through runoff for most of the irrigation schemes and or left by the retreating nearby Lake Jipe for Kamleza-Kimoringo irrigation scheme soils. However the irrigation water has potential for salinization but not to the extent reported in this paper. These salts are removable through drainage and interventions that dissolve the salts or remove them from the soils like pytoremediation, use of manure and crop residue incorporation.

Competitiveness of shelled groundnut markets in Central Malawi: A market integration approach

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To increase production of groundnuts in Malawi, several high yielding varieties have been developed and released. However, their rate of adoption among farmers is low, consequently affecting productivity of the crop. Among other factors well functioning (integrated) output markets in general increase returns to farmers through reduced marketing costs and fast exchange of price changes between markets. Farmers would respond to well integrated markets by increasing production and adoption of high yielding crops. Market integration, a proxy to market efficiency, describes the degree of price transmission and movement of commodities between spatially separated markets. Information on market integration is crucial in influencing farmers' production decesions. Food security and price stabilization policies also utilize information from market integration studies. As an important source of food, income and soil fertility improvement among smallholder farmers in Malawi, we sought to understand the extent of integration of shelled groundnut markets. Based on availability of monthly retail price data with minimal gaps for the period January 2004 to December 2008, we selected 11 markets across the country; 6 local and 5 national. The 6 local markets are from central of Malawi, a major production region of groundnuts, while for the national, 4 are from the central 2 are from the South and North of Malawi respectively. Summary statistics were computed to understand price volatility. Pair-wise correlation analysis was conducted to measure association of markets. Johansen co-integration test was carried out to unveil number of cointegrated markets and long run stable relationships. Vector error correction mechanism (VECM) was applied to estimate the speed of adjustment of prices to equilibrium.We observed high values of standard deviation statistic in some markets implying that prices were relatively unstable. Low correlation coefficients were recorded in all the markets suggesting a weak association among markets. Johansen co-integration test revealed 6, 2 and 1 cointegrated markets for local-national, local and national markets respectively ,meaning few markets exhibited long-rum stable relationship. Low but significant coefficients of speed of adjustment indicate that prices were slow to adjus to equilibrium after deviation. Nevertheless, most of the coefficients of the cointegration vectors of the national markets were significant implying that they are important in explaining price changes in the local markets. The study therefore reveals a weak integration of groundnuts markets in Malawi for the study period, suggesting the existence of some barriers in the markets. These obstacles may take the form of poor price information flow and road infrastructure, resulting to slow price transmission and high cost of transporting produce between markets. The implication of this is that excess supply or excess demand of groundnuts would persist for a long time driving prices down or up, consequently affecting farmers' production decisions in general. The study therefore suggests improvement in road infrastructure and commodity market exchange bureaus to facilitate movement of groundnuts grain and flow of price information between markets.

Integration of commercial products into soil fertility practices as potential options for acclimatilization of tissue culture banana

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Tissue culture (TC) banana plantlets at the *in vitro* stage are delicate and lack microbes and minerals that are essential for establishment and subsequent growth. Some microbes are known to function best under certain soil threshold levels of macro and micronutrients and have been associated with growth and performance of TC banana. A greenhouse study was conducted to evaluate the effect of combining two commercial biological products; Rhizatech and ECO-T (mycorrhizal and *Trichoderma* based products respectively) with various sources of Nitrogen and Phosphorous including Mavuno, minjingu phosphate rock,

CAN, manure and diammonium phosphate (DAP) on growth and performance of TC banana under Vertisol and Rhodic Ferralsol soil conditions. The performance of plants was significantly ($P<0.05$) affected by the combinations of nutrient sources depending on the soil type. The performance of plants in the Vertisol was enhanced by over 100% magnitude with *Trichoderma* combined with either manure DAP or combined with Mavuno as compared to the sole application of *Trichoderma*. Performance of plants treated with combination of mycorrhiza and either mavuno and minjigu rock phosphate was consistently better in the Rhodic Ferralsol than for plants treated with either mycorrhiza alone or fertilizer alone. Optimization of biofertilizer can be achieved when integrated with organic and inorganic fertilizer.

Soil microbial diversity and alien plant invasion: Insights through a multi-scale approach

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In the present globalized world, alien invasive species attract a lot of attention because of the harmful ecological and economic impacts they may inflict upon the ecosystems in non-native biogeographical regions. Thus, attempts have been made to plausibly explain as to why some alien species undergo profound shift in their ecological fortune from being minor components of their native ecosystems to becoming devastating dominants of non-native habitats. Untangling this ecological mystery undoubtedly holds promise in the prediction and management of already established, and future species invasions. The present study was undertaken to a) assess the mycorrhizal status of alien plants in the Kashmir Himalayan region of India, b) to explain the role of AM fungi in invasiveness of some flagship invasive plant species, such as *Conyza canadensis*, and c) to examine the impact of invasive plants on soil microbial communities. We used a multi-scale approach to evaluate the impact of plant invasion on soil microbial diversityby comparing the patches invaded by *C. canadensis* and similar control (uninvaded) patches both in native Québec (Canada) and in the introduced Kashmir Himalayan region (India), using both conventional (morphological) and molecular methods. The results of the study allowed us to conclude that the alien plants of Kashmir Himalaya harbour high mycorrhizal colonization and these mutualists play a significant role in their invasive success. Moreover, belowground AMF communities and aboveground herbivores synergistically promote plant invasiveness. In turn, plant invasion causes a shift in the density, composition and diversity of AMF spores in the rhizospheric soils. Metagenomic results yielded a discernible shift in community composition of soil microbial communitiesin native and invaded habitats with higher number of bacterial species found in the patches invaded by *C. canadensis* in comparison to similar control (uninvaded) patches.Invaded patches also harboured more bacterial species unique to them as compared to that in control patches. Moreover, significant reduction in the number of restriction fragment sizes was found in the Indian soils in comparison to Canadian soils, thus indicating reduced diversity in the invaded range. The results favour the conclusion that invasion by alien invasive *C. canadensis* alters soil microbial structure in the patches invaded by it in the Kashmir Himalayan region. Finally, we discuss the possible impacts of invasion-induced shift in belowground diversity on the aboveground plant diversity in the floristically rich and geographically unique Kashmir Himalayan region.

Cropping systems and existing technologies of soil fertility management should be considered to improve crop production in West Africa

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Various technologies of soil fertility management are used in African smallholders' farms, leading to a high diversity of soil quality and crop yields. In this study we wanted to understand this diversity in West African context and identify key technologies improving the yields of sorghum (*Sorghum bicolor*) and cowpea (*Vigna unguiculata*), staple food and cash crop respectively. The study was conducted in a rural area from the centre west part of Burkina Faso which has in average 800 mm rainfall per year. We selected together with farmers' organizations, fields of sorghum and cowpea grown in mixed or in single cropping on lixisols, located around a national agronomic research station within a radius of 15 km. We obtained by this way 130 fields of sorghum and cowpea in mixed cropping, sorghum being the main crop and 30 cowpea fields in single cropping. The farmers of the 167 fields were interviewed regarding the forms and the quantities of fertilizers applied and the use of animal draft for soil work. We recorded information about the proximity of the field to the habitation, the presence of techniques against soil erosion, and the sowing density. Two micro plots of 10 m^2 were installed on the fields to evaluate crop yields. Soil samples were taken in those micro plots at 0-10 cm of depth and analysed for their pH, total C and N and available P contents. The geographical coordinates of the fields were recorded and the distances between those fields and the research station were calculated. Our results showed that single cropping cowpea fields receive more mineral fertilizers, less organic matter and have less variability in sowing density compared to the mixed cropping sorghum-cowpea fields. The single cropping cowpea fields are close to the habitation at 30%, under techniques against soil erosion at 40% and worked with animal draft at 80%, while for mixed sorghum-cowpea fields, 11%, 60%, 90% were observed for these three parameters respectively. A high variability of soil chemical properties was observed in both cropping systems which resulted to high variability in yields. More than 50% of sorghum and cowpea grain yields were less than 500 kg ha^{-1} while some farmers reached grain yields between 1.5 and 2 t ha^{-1} for sorghum and 1t ha^{-1} for cowpea. Only 40% of sorghum yields variability was explained, with compost addition and techniques against soil erosion as being the main factors. On the other hand, about 70% of cowpea yields variability was explained, with soil available P, field proximity to the habitation and techniques against soil erosion as being the main factors. Fields receive more attention regarding soil fertility management when they are more close to the research station, mostly for the single cowpea cropping fields. Our results point out the necessity of considering the cropping systems, existing technologies and their transfer to smallholders for improving crop production in Africa.

Measuring biomass production and nitrogen fixation in fodder trees on smallholder farms in Kenya

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Leguminous fodder trees are important high-quality feed resources for smallholder farmers. Previous work on the performance of fodder trees on station and on farmers' fields did not consider the diversity and heterogeneity within the smallholder farms. Farmers have preferred socio-ecological niches for the planting of fodder trees, but knowledge is lacking on the biomass production and nitrogen fixation of different tree species in these niches. Thus the objectives of the experiment were to: 1) determine biomass yield of *Calliandra calothyrsus* and *Leucaena trichandra* grown on three identified niches in four sites of Central (Kirege and Machanga) and Western (Emuhaya and Teso) Kenya with contrasting biophysical and socioeconomic conditions; 2) determine the amount of nitrogen fixed by the fodder trees; and 3) determine variation in 15N enrichment with soil depth. A field experiment involved growing of *C. calothyrsus* and *L. trichandra* in a randomized complete block design (RCBD) with four replications in three identified niches (along contour, internal boundaries and degraded land) in the 4 sites. Cumulative biomass of cut hedges of the two fodder tree species was measured and the amount of nitrogen fixed was estimated by using 15N abundance method. A greenhouse experiment involved growing maize in pots of soil collected from different depths from one farm in each of the four sites. Total shoot biomass and δ15N content of the maize was determined. GenStat software was used to carry out analysis of variance of measured parameters and means were separated using $LSD_{0.05}$.Biomass yield of the cut fodder trees grown in degraded land was significantly low ($P < 0.001$) than in other niches with the lowest (3.7 Mg DM ha^{-1}) from *L. trichandra* in Kirege than in other niches. *C. calothyrsus* grown in degraded land in Teso performed significantly ($P < 0.001$) better (25.6 Mg ha^{-1}) as compared to the other niches. Generally *C. calothyrsus* was significantly ($P < 0.001$) better than *L. trichandria* in all the sites. The amount of N fixed followed a similar trend to fodder biomass, with *C. calothyrsus* in Teso fixing the highest amount (616 kg N ha^{-1}) and *L. trichandra* in Kirege the lowest amount (7.8 kg N ha^{-1}). This implies that biomass production and hence nitrogen fixation of the fodder tree species depend on the niche where farmers will choose to grow them. Biomass yield of maize shoot biomass decreased with increase in soil depth except at Machanga site which was consistently low at all depths. δ15N of the maize planted in soil from different depths varied along soil depth per site with differences becoming less from a depth of 60 cm downwards to 200 cm. In most sites δ15N was inconsistently higher in depths of 0 - 20, 20 - 40 and 40 - 60 cm indicating that most of the variation in soil δ15N is within the first top 60 cm.

Soil organic matter variability and its impact on maize yields in smallholder farms in Central and Eastern Kenya

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Improving soil fertility management is widely recognized as a critical factor in addressing food insecurity and poverty in sub-Saharan Africa. Strategies to arrest soil fertility decline and raise agricultural productivity include efficient nutrient management and supply accompanied by good agricultural practices. Ease of fertilizer access may be one way of increasing the use of fertilizers to raise soil organic matter, an indicator of soil quality. A study was carried out to assess the spatial variability of baseline soil organic matter content and its effect on maize productivity in farmers' fields over a period of three seasons. Sites were selected in Embu, Kandara, Yatta and Tharaka districts in central and eastern Kenya on the basis of rainfall potential and accessibility to inorganic fertilizers. Nine farmers were selected in each district to represent different management levels. Baseline soil fertility and farm nutrient management were determined before onset of on-farm field trials. Treatments included: control; farmyard manure (FYM 10 t/ha); $N_{120}P_{60}K_{100}$; $N_{60}P_{30}K_{50}$ + FYM 5t/ha; $N_{60}P_{30}K_{50}$ + FYM 5t/ha + lime (0.5 t/ha; $N_{60}P_{30}K_{50}$ + FYM 5t/ha + CaMgS micronutrients and $P_{60}K_{100}$, $N_{100}K_{100}$; $N_{100}P_{60}$. Baseline surveys indicated that total soil nitrogen and organic carbon were very low at 0.01-0.19% N and 0.4 to 1.1% C, respectively, across the four sites. Farm nutrient balances were influenced by agro-ecological zone and farmer socio-economic status. Yields of major crops grown in the sites were generally low with large yield gaps. Application of nitrogen, phosphorus, farmyard manure and lime resulted in maize yields of 3.0 to 4.3 tonnes/ha with increases of 5 to 45%. A strong nitrogen and phosphorus interaction was noted in the higher rainfall areas. Thus promotion of soil fertility management strategies is a site-specific exercise.

Strategies for enhancing common bean productivity in Kenya

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Legumes are important components of sustainable agricultural productivity due to their capacity to fix free nitrogen in the air through biological nitrogen fixation. They also provide the bulk of the dietary protein of most rural communities in sub-Saharan Africa. However, the productivity of grain legumes is rather low due to low soil fertility as well as other biotic and abiotic constraints. Legumes are usually grown as intercrops by resource-poor women who rarely use fertilizers. In Kenya, beans are the most popular food legume, but yields are low in the range of 200-950 kg ha^{-1} under smallholder farms. There is need to find strategies for utilizing the nitrogen fixation potential by identifying appropriate germplasm for each agro-ecological zones and soil fertility regime. A study was carried out to evaluate five popular varieties of beans, *Phaseolus vulgaris* L. cvs. Rose coco, Canadian Wonder, Mwezi Moja, Mwitemania and Wairimu in an on-station experiment. The treatments were: un-inoculated,

unfertilized control (Nil), inoculated (I), fertilized with no inoculation (40 kg N/ha - N) and, fertilized and inoculated (20 kg N/ha -IN) replicated four times. Phosphate fertilizer was applied at the rate of 30 kg P/ha as a blanket treatment. Results indicated that there were significant ($p<0.05$) differences between the varieties. Bean grain yields ranged from 1.07 t ha^{-1} (Wairimu) to 1.71 t ha^{-1} for Mwitemania. Bean stalks ranged from 0.95 t ha^{-1} for Wairimu to 1.58 t ha^{-1} for Canadian Wonder while the harvest ratio of grain: stalk was about 1.2:1. The varieties, Canadian Wonder and Mwezi Moja responded positively to N fertilizer application but not to inoculation. Wairimu and Rose coco responded to inoculation while while Mwitemania did not respond to either inoculation or N application. Application of fertilizer at 40 kg ha^{-1} gave significantly ($p<0.05$) higher average yields (1.73 t ha^{-1}) than the inoculated treatment (1.27 t ha^{-1}) which was significantly higher that the control (1.19 t ha^{-1}). This may be an indication that inoculation did not meet the total nitrogen requirement for the crops or there could have been other constraints that may need to be addressed further. However, it was notable that all the varieties gave significantly higher yields (2-3 times) than those reported under farmer managed fields which may be attributed to good agricultural practices with minimal inputs.

Integrated soil fertility management strategies for improved crop production in Kenya

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Poor soil fertility and nutrient depletion continue to present major obstacles to food sufficiency and poverty reduction in the sub-Saharan Africa. Low adoption of improved soil fertility management technologies has led to low crop yields and land degradation. Soil fertility related issues are a major concern to Kenya as attested by many policy documents and research projects. As cultivable land becomes scarce due to rising population and continuous land sub-division, intensive agricultural production will be the key factor in improving food security and alleviating poverty. This calls for a holistic approach to research on soil fertility to embracing the full range of driving factors and consequences, namely biological, physical, chemical, social, economic and political aspects of soil fertility decline. A recent survey was carried out to review legacy data from numerous research projects and studies carried out in the country for suitable complementary technologies which could be used to address issues of soil fertility decline and poor crop yields. The objective of the review and document successful ISFM technologies in Kenya to enable stakeholders and policy makers make informed decisions for sustainable land management under various agro-ecological zones of the country. The methodology used included visiting various research centres and university libraries as well as individual scientists' offices. Information was collected in either hard or soft copies whichever was convenient or available. More literature was accessed from online journals and libraries at international centres. This report gives a synthesis of data collated from 225 papers and reports which included peer-reviewed literature in local and international journals, books, conference proceedings, technical reports and unpublished materials spanning the period from 1960 to 2010. The information was evaluated and categorized into four groups, that is, nutrient sources, cropping systems, agro-ecological zones and geographical regions. Four main geographical regions were identified as, western, central, eastern and coastal regions while the main nutrient sources included inorganic fertilizers, agro-forestry, manures, green manures, improved fallows and legume rotations and intercrops. Collectively, the available data suggests that combined organic and inorganic resource inputs were the most considered interventions (65%). Maize crop was the most targeted crop (61%) while other crops included sorghum, pigeon pea, cowpeas, finger millet, common beans, local vegetables, cotton and wheat. Challenges encountered in harmonization included lack of comprehensive soil data, varied and unspecified treatment combinations as well as lumped data sets.

Intensification of maize systems with leguminous trees and shrubs in semi-arid Tanzania

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Land degradation due to poor farming practices and forest degradation and deforestation is one of the main constraints for increased agricultural productivity in semi-arid tropics. Integrating leguminous trees and shrubs into farmlands can address this problem through improved soil fertility and on-farm wood supply. Boundary tree planting is one of the appropriate technologies for on-farm fuel wood production in dry lands. However, little is known on the optimum spacing and interactions of boundary trees with nutrient management options to enhance farm productivity. Two split-split plot experiments, one for *Acacia polyacantha* and another for *Eucalyptus camaldulensis*, wereestablished to assess the effects of spacing and pruning of boundary planted trees and nutrient inputs (intercropping of maize with *Tephrosia* and/or pigeon pea, fertilizer, and cattle manure) on yields of wood, maize, and pigeon pea. After 24 months, diameter at breast height (DBH) and crown sizeof trees did not vary with spacing indicating absence of intra-specific competition. *E. camaldulensis* doubled DBH (4.4 cm) and wood yield (4.4 Mg/ha) compared to *A. polyacantha*. Wood yield was the highest at 2x2m for both species (4.4 Mg/ha versus 7.7 Mg/ha). This amount can satisfy the household fuel wood demand for 1.4 to 2.5 years. Pruning branches of *A. polyacantha* increased maize and pigeon pea yields in the second and third seasons, reflecting reduced competition for aboveground resources. Corresponding yields for *E. camadulensis* were unaffected by pruning, possibly reflecting belowground competition by tree roots. Maize yield at 1m (0.50 to 1.16 Mg/ha) was significantly lower than yields at 3m and 6m (0.62 to 1.32 Mg/ha) from the boundary. This implies that belowground competition limited crop growth closer to the tree row. Fertilizer and manure additions enhanced soil nutrients; maize and pigeon pea yields compared to intercropping and control treatments. Root pruning, which may be labor intensive, is not necessary within 3 years after planting since planting crops 3m from border trees may reduce inter-specific competition. This study demonstrates the potential for boundary tree planting and integrated nutrient management approaches in intensifying maize systems to improve crops and wood yields.

Client-focused extension approach for disseminating soil fertility management information in Central Kenya

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Soil fertility replenishment in sub Saharan Africa (SSA) is critical to the process of poverty alleviation. Although researchers have developed many soil fertility improving technologies, adoption of the technologies is low mainly because of inadequate awareness of the technologies and lack of requisite resources. Extension agents are responsible for enhancing farmer' acceptance of innovative practices from research which leads to increased farmers' productivity and income. Hence, the study sought to investigate factors considered by agricultural extension agents in selection of communication channels to disseminate soil fertility information in the central highlands of Kenya. Questionnaires were used to elicit information from 105 extension agents. Both descriptive and inferential statistics were used for data analysis. In choosing the communication method to be used in dissemination of soil fertility management (SFM) practices, target group was scored as the most relevant factor followed by type of SFM, time available then number of staff sequentially. Education was perceived to highly influence the selection of workshop while age was perceived to highly influence the selection of video showing as extension methods in dissemination of SFM.The implication of the study is that diverse communication channels should be utilized to get to farmers of different socio economic characteristics.

Approaches towards effective integrated soil fertility interventions in smallholder farms of Central Kenya

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Production of maize in small-scale farms of less than 5 ha is highly constrained in Central Kenya. Soils in these farms are highly depleted due to production demands of a growing population. Integrated soil fertility approaches are required to improve production capacity of these farms. Eight diagnostic fertilizer treatments (NPK, NPK+lime, NP, PK, NK, Mavuno, NPK+manure and Control) were tested in 32 farms selected from sixteen clusters of Kandara sentinel site to (a) diagnose the multi-location fertility difference between fertility management regimes, (b) to determine which fertilizer treatments can be used to increase maize yield and (c) identify priority areas of interventions. Soil samples at 0-20cm depth were taken from each farm for fertility analysis while the eight fertilizer treatments were laid in 10 plots in each farm for the September-January 2011-2012 season. Thereafter harvest and fertility data from each treatment and farms were analyzed to determine effects of farmer and treatments on dry matter yield and grains weight. Results obtained indicated that there was a significant difference in soil fertility management between farmers ($p<0.001$) in relation to dry matter yield and a significant difference in grain weight between treatments ($p<0.01$). Treatments NPK+Lime, NPK+manure and mavuno showed higher dry matter yield and grain weight and can be used to improve soil fertility in farms that are characterized by low fertility and low dry matter yield.

Benefits of ISFM in new maize and green gram varieties in semi-arid Eastern Kenya

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Maize and green gram are important staple food for most Kenyans. Their production in semi arid areas of Kenya is low due to mainly droughts, low soil fertility and unsuited varieties among other factors. KARI in collaboration with other stakeholders notably CIMMYT have come up with promising high yielding low input drought tolerant maize varieties. KARI has also developed a high yielding green gram variety. Adoption of these varieties has remained low. This paper reports the findings of a farmer, researcher and extension assessment of the social, economic, soil fertility and environmental impacts, of the maize and green gram varieties and associated ISFM practices being recommended for widespread adoption. The results would provide ways of designing methods of scaling up the improved practices in order to improve maize and green gram production in the semi arid areas of Eastern Kenya. Two maize varieties (KDV1 and KDV6) and one improved green gram (N26) variety were evaluated by 18 smallholder communities in 18 trial sites in Machakos county (9 sites in Mwala district and 9 in Yatta district) on farmers fields during short rains (SR) 2011/2012 season. Accompanying ISFM practices evaluated alongside were fertilizer application (type and rate) and tied ridging to improve rain water use. Evaluation sites, crop varieties and associated agronomic practices were identified from inventories at KARI Katumani and Embu by panels of smallholders. Each site was managed by a group of farmers. Results obtained indicated that yield increase and economic benefit over the farmers varieties was more than 50% for both maize and green gram varieties over their respective local varieties. Ranking of the varieties by the participating farmers indicated that men farmers ranking conformed with the grain yields performance of the varieties but the women ranking did not. The results demonstrate that wide spread adoption of these simple practices is feasible and can result in significant productivity gains. In this instance, women considered other things in addition to performance in grain yield while ranking the varieties.

Reducing the *Striga hermonthica* seed bank and improving soil fertility in Western Kenya

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Maize is the main crop/staple food for over 80% smallholder farmers in Western Kenya and its production average 0.2-0.5 t/ha which is below the national average of 6 t/ha. *Striga hermonthica* infestation and declining soil fertility are two major constrains to maize production in the region. The parasitic weed attaches and penetrates the host roots (its growth is chemotrophic) and utilizes host root system for photosynthates, water and minerals salts thereby reducing maize productivity and driving several rural households into extreme poverty.Continuous farming with inadequate nutrient input supply drives the soil to be N and P deficientHowever the low yields can be managed throughuse of Imazapyr Resistant (IR) maize variety (WS303) and nitrogen (N) fertilizers.The main objective of the study was to evaluate the effect of IR maize in combination with inorganic N-fertilizer in reducing striga seed bank, improve the soil fertility and increase maize yields .Experiments were conducted during short rains of 2011 under naturally striga infested fields of high and low soil fertility status in Western Kenya (Bondo, Siaya and Vihiga). Two maize varieties (WS303 and DH04) were planted in the main plot and N-rates (0 and 60 Kg N/ha) assigned to subplot. Soil samples were taken prior to planting and at harvest for analysis of selected physiochemical elements and striga seed bank determination. Data were collected on Striga plants emerged at the 6th, 8th and 10th weeks after planting (WAP) and maize grain yields at physiological maturity. Preliminary results showed significant ($P \leq 0.05$) response to plots that had WS303 were observed with decreased striga stands emerged (109/ha). The highest number of number of striga stands emerged (398/ha) were realized in plots that had DH04. N-fertilizer had significant effect on yield but no effect on striga emergence. Generally IR maize yielded higher (1.5 t/ha) than DH04.These findings showed that farmers can reduce strigadensity improve soil fertility and increase maize grain yield by combining IR maize with inorganic N-fertilizer.

Effects of different lime rates and liming methods on maize yields in Western Kenya

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Lime use in Western Kenya is still low because of low returns compared to those of fertilizers containing Phosphatic, nitrogenous or potassium elements, lack of awareness on the importance of lime, high cost of purchasing and transporting and lack of appropriate method of applying lime by small holder farmers. The study aimed at finding out an appropriate rate and method of applying lime and to investigate further on lower rates of lime with spot application method towards affordability in Western Kenya. On farm experiments were conducted in North Kakamega and Ugenya districts, in a 3x4 factorial arrangement (three methods of lime applications: spread, band and spot and four rates of lime: 0, 2, 4 and 6 t/ha) in RCBD with four replicates. The study was conducted during 2010 LRs, SRs and 2011 LRs, test crop used was maize (*Zea mays*) and the source of lime was Homa lime company. while to meet the second objective, a different experiment was laid out in RCBD replicated thrice (treatments were; 0.5 t/ha, 1 t/ha, 1.5 t/ha, 2t/ha and control during 2011 LRs All treatments were supplied with Phosphorus (26 kg/ha) and nitrogen (75 kg/ha) except control plots in the first experiment while in the second experiment Phosphorus and nitrogen were supplied to all the treatments. Results indicated that highest maize grain yield could be found from applying 6 t/ha of lime by band method in both districts because of high soil-lime contact within the rooting area of the crop. In North Kakamega district yield increased by 2.02 t/ha from control while in Ugunja district, it increased by 3.10 t/ha. However the yield increase in North Kakamega were not significantly different from band (4t/ha), spot (2, 4 and 6 t/ha), broadcast (4 and 6 t/ha) while in Ugunja it was not significantly different from spot (2 and 4 t/ha), broadcast (2, 4 and 6 t/ha) ($p=0.05$). For the second experiment the The results showed no significant increase in grain yield, pH and P ($P=0.05$) in both districts. To conclude, band method is appropriate in applying lime for the two study districts, rates lower than 2 t/ha cannot significantly increase grain yield when applied by spot method.

Quality assurance of BIOFIX inoculants in Kenya

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Legume inoculants are produced in Kenya by MEA Fertilizer Ltd. under the trade name BIOFIX. While no industry standards have yet to be established in Kenya, it is nonetheless important that an independent quality assessment be conducted. This service is conducted by the University of Nairobi MIRCEN Laboratory. Product targets are at least 109 rhizobia per gram of inoculant and no more than 107 contaminants. Inoculants are submitted to MIRCEN from the BIOFIX factory in Nakuru and assessed on CR YMA in triplicate using the drop plate method, with the 10^{-5} to 10^{-7} dilutions plated. Two samples are measured per batch. Results are entered into a spreadsheet utility to calculate the inoculant population, total contaminants and their respective CVs. A recent series of batches of BIOFIX averaged 6.5×10^9 cells (CV 25%) when sampled off the factory curing shelf. Experimental inoculants prepared by MIRCEN averaged 3.5×10^9 cells (CV 26%). A pilot liquid formulation inoculant contained 1.5×10^9 cells (CV 33%). Quality assurance results are summarized into a "sample and batch report" and forwarded to the MIRCEN Director, MEA's Factory Supervisor and other concerned parties. Each batch of BIOFIX consists of about 1000 packets of inoculant, resulting in 0.2% quality assurance sub-sampling. The reporting time is currently too late to intercept inferior samples from the manufacturer's inventory. Contaminants continue to exceed targets. Some inoculants appear to contain mixed cultures. These shortcomings are currently being addressed by the factory and laboratory.

A Paradigm shift: Everlasting greening in the summer rainfall regions of Southern Africa

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Southern Africa is a drought stricken area with limited water resources and degraded arable land. As a counteraction, a paradigm shift in all three tiers of agriculture is proposed. The emphasis should not *per sé* be on the yield of specific commodities, but rather on optimising the productive potential of agricultural systems at field or watershed level. One of the greatest challenges for agro-ecologists is to translate general ecological principles, conservation agriculture technologies, and natural resource management concepts into practical advice that is relevant to the needs and circumstances of farmers, especially small-scale farmers. These strategies must be applicable to the highly heterogeneous and diverse conditions in which southern African farmers function. The result of implementing applicable integrated strategies will be farming systems that are environmentally sustainable, and are based on the use of local resources and indigenous knowledge.Central to the above is the need for more knowledge regarding the biological processes that makes soil systems more productive and more sustainable. To capitalise on biological potentials, a holistic approach is needed that encompasses both macro- and microorganisms. Moving away from conventional farming, a shift towards a multi-disciplinary approach is proposed that not only deals with production but also includes socio-economic aspects. There is a need to design future farming systems that are strongly rooted both in science (agro-ecology) and in practice (conservation agriculture technologies). Agro-ecology includes the ecosystem approach to sustainable crop production, and diversified intensification that includes animals.Soil is not only a medium to support plant growth, but is one of the richest ecosystems. Unravelling the complexity of soil as a living system only started towards the end of the previous century. Advances in biotechnology over the last 30 years have been the key to unlocking the "underworld". In southern Africa, the study of living soil and its complexity is still a hugely neglected science, while there is an ever increasing demand for proof to farmers that the enhancement of soil life improves farming systems.The greatest advance towards everlasting greening and sustainable production intensification in South Africa was the introduction of conservation agricultural technologies, such as minimum or reduced tillage. In the rest of southern Africa, the adoption of this technology is still poor. The major constraints in the adoption and perseverance with conservation agriculture are: the complexity of the adoption process; lack of commitment, awareness and knowledge; access to appropriate equipment, finances, control of grazing animals and weed fatigue. A solution is to demonstrate best practices per geo-ecological zone, and raise awareness at all levels of society. Furthermore, there must be political will to green southern Africa forever. This can only be done by increasing funding for research, and the implementation of agro-ecological based technologies.

Support of the ARC-Plant Protection Research Institute to Agriculture in South Africa and other African Countries: Promotion of soil health and plant microbiology

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The ARC-Plant Protection Research Institute has a long history in the fields of Plant Microbiology and Plant Pathology. This Programme primarily covers the following disciplines: plant pathology (virology, bacteriology, mycology and nematology) and the biosystematics of the mentioned organisms. Research is conducted on a broad range of plant pathogens of various crops, including soil-borne and post-harvest diseases. Soil health and biological control strategies is promoted through the development of technologies enhancing beneficial micro-organisms such as nitrogen fixers, plant growth promoting and plant protecting bacteria, as well as mycorrhizee . Recent projects also involved development of small business units on mushrooms production, measurements of mycotoxins in grains, and surveys of the distribution of American foul brood disease of honey bees in some southern African countries. In the research conducted, there is strong emphasis on natural resource protection, the enhancement of agro-ecological principals and conservation agriculture technologies. Among others, the Institute is the custodian of four national culture collections affiliated with the World Federation of Culture Collections, and provides biosystematic support to students and researchers. These collections are the South African Rhizobium Culture Collection which also includes other plant growth promoting bacteria, the Plant Pathogenic and Plant Protecting Bacterial Collection (PPPPB), the National Collections of Fungi (PPRI), and the National Collection of Nematodes. Approximately 12000 strains are available in the abovementioned microbial collections. The National Collection of Nematodes houses an irreplaceable specimen collection of South African and foreign material, including type material, with associated literature and electronic reference sources. In addition, we maintain the largest collection of plant pathogenic viruses, antisera (>1600) and seroreagents (>300) in Africa.Except for research, technology transfer is one of the major activities within the Institute, and training courses on various levels are offered to farmers and extension officers serving South African agriculture. Young scientists and researchers, as well as local and foreign agricultural support groups, are trained in courses presented by scientists in the Institute. The soil-borne plant diseases group in Stellenbosch hosts an annual symposium on the latest developments regarding soil-borne plant diseases. Expertise available within the Institute facilitates the provision of a variety of services, including diagnostic, identification and analytical, as well as general information.

Reduction of P sorption capacity in cocoa growing soils by use of integrated fertilization in Cote d'Ivoire

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In acid strongly P-sorbing soils of Côte d'Ivoire, P is among the nutrients that most limits plant production.For the success of cocoa (*Theobroma cacao* L.) replanting, application of P to soils is one solution to ensure cacao growth and productivity. To assess the effect of different P applications on cacao production, we conducted a field trial on the Ferrasol at the cocoa research station (Divo, Côte d'Ivoire). Six treatments were tested: T_0 = no P application; T_1 = 8 t.ha^{-1} compost; adding 184 kg P_2O_5 ha^{-1}; T_2, T_3 and T_4= T_1 plus 184 or 92 or 70 kg P_2O_5 ha^{-1} P_2O_5 applied as superphosphate (SP), respectively T_5 = 184 kg ha^{-1} P_2O_5 applied as SP. The compost was produced locally with cocoa pods husks and poultry litter. Two years after cacao replanting, fruit development and yields were measured. Also, we analyzed modifications in soil P availability by determining the soil solution P concentration (C_P) in water extract (1g:10ml) and associated P sorption-desorption dynamics after 1 d, the P extracted by the Olsen-Dabin chemical method and the total P content on samples taken along the soil profile at 4 depths: 0-5, 5-10, 10-15 and 15-20 cm layers. Finally, main soil properties of all soil layers were determined. 184 kg P_2O_5 ha^{-1} applied as compost did not increase significantly the fruit developments and yields whereas 184 kg P_2O_5 ha^{-1} applied as SP increase significantly but slightly yields. All compost + SP treatments increased significantly yields in relation with the amount of SP. These results were related to the improvement of the soil P status mainly of the 0-5 cm layer but also for deeper layers. All indicators (C_P, P-Olsen-Dabin and total P) shown similar trends. For example, the C_P value for T_0 was extremely low close to the detection limit of the colorimetric method (<0.005 mg P L^{-1}). The C_P values of the 0-5 cm soil layer increased with applied P from 0.015 (±0.003) mg P.L^{-1} for T_1 to 0.452 (±0.003) mg P.L^{-1} for T_2. As a consequence, sorption-desorption curves shown a decreasingly ability of soil to sorb P both by applying water-soluble P and compost. Further works are required to distinguish the respective effect of each factor. Finally, the greatest increase in growth and yield is observed when 8 t.ha^{-1} compost + 184 kg.ha^{-1} P_2O_5 was applied. It is likely due to the positive and synergistic effect of mixing organic and phosphate fertilizer to reduce P sorption capacity in cacao soils. Also, the distribution of P along the soil profile might also play an important role.

The role of researchers in bridging information gaps between farmers, extension agents and policy makers for improved food production in Africa

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The livelihood situation in Africa has been described as dire and deteriorating with hunger and poverty projected to worsen in the coming years. Statistics show that 80 % of all Africans are living on a daily income of less than US$ 2 while nearly half of the population are struggling to survive on US$ 1 or less in a day. It is reported that more than 200 million Africans are suffering from malnutrition while food aids continues to increase every year. Without adequate food supply the lives of people are jeopardized and especially that of children. Farmers have been losing their purchasing power in the last 25 years, and farm income levels are estimated to be below $200 per person per year. On the other hand, researchers have continued developing new technologies but adoption by farmers has been very low. In many parts of Africa, farmers are still using old technologies even in areas where new and sustainable technologies have already been developed. The big question remains why the current scenario even after a lot of resources have been channelled to researchers, research projects and organisation working on food security has continued to increase over the years. This paper identifies some of the major reasons why the scenario remains so. There remains a big information gap between researchers, farmers, extension agents and policy makers. The paper identifies ways and means on how this research gaps can be eliminated.

Managing maize yield through nutrient targeting on light-textured soils in sub-humid climates

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Nutrient resources targeting by smallholder farmers for optimized use efficiency has remained poor resulting in sub-economic returns to investments. We sought to establish efficient strategies for use of nutrient resources so as to narrow the exploitable yield gap in maize production on heterogeneous light-textured soils under rain-fed conditions. A multi-locational nutrient omission study was carried out in Eastern Zimbabwe, during the 2010/11 and 2011/12 cropping seasons, across nine on-farm sites with soil C ranging from 0.33–0.70%, and clay content between 4–19%. Treatments used were: i) Control, ii) NK, iii) NPS, iv) PKS, and v) NPKS. The nutrients PKS were basally applied at 40, 60 and 40 kg ha^{-1}, respectively. The rate of N application was deemed a function of rainfall, with a mandatory initial application of 20 kg ha^{-1} N at planting and two subsequent splits of 50 kg ha^{-1} N if soil moisture permitted. Rainfall water productivity (kg grain mm^{-1}, RWP) was used as a proxy for water use efficiency for the different nutrient management strategies. In both seasons, only 70 kg ha^{-1} N could be applied across all sites as moisture limitations forced withholding of the second N topdressing targeted at maize anthesis stage. Maize productivity was significantly influenced by nutrient management across sites for both seasons, with a significant site x treatment interaction ($P < 0.01$). The first season had maximum yields of only 1.55 t ha^{-1} for the NPKS treatment due to a severe drought. During the second season, maize yields across sites ranged from 0.25–0.84 t ha^{-1} for the control and 2.05 – 4.97 t ha^{-1} for the NPKS treatment. The corresponding RWP were 0.38–1.13 kg grain mm^{-1} for the control and 3.15–7.66 kg grain mm^{-1} for the NPKS treatment. Using NPKS-mean yield of 3.56 t ha^{-1} as a proxy for 'attainable' yield, the corresponding N, P and K response factors

were 0.56, 0.45 and 0.09, indicating poor response to K and highest response to N application. These results suggest that balanced nutrient management has an overriding effect on maize grain and water productivity, but only guaranteed when soil C > 0.45%. Nitrogen and P remain the most limiting nutrients, and complementary organic nutrient management approaches should be employed to increase soil C and sustain soil productivity. Variable N application strategies must be an integral component of farmer management if losses related to fertilizer investment are to be minimised under the risky rain-fed production system.

The curse of nitrogen deficiency in Africa: can pigeonpea play saviour?

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Compared to other continents, Africa is the only region where food production levels have continued to plummet over the last decade. As a result, a sizeable proportion of the continent, especially in semi-arid areas suffer chronic food shortages and hence depend of relief supplies for survival. The situation is bound to worsen with the anticipated climate change.Most farmers, especially in semi-arid Africa, harvest about 500 kg ha^{-1} of maize against potential yield of 2.4 t ha^{-1}. The low yields are partly due to low and erratic rainfall, and low soil fertility. On average, these regions receive adequate rainfall in only two out of every seven years. Thus, droughts and crop failure are very rampant. Most soils have low organic matter content and are deficient in essential plant nutrients, especially nitrogen (N). In fact, nitrogen has been declared to be the most limiting nutrient to crop production on the continent.A number of options have been proposed to correct the situation but their level of adoption has remained very low. For instance, few farmers have embraced fertilizers due to their exhorbitant prices, risks associated with variable rainfall and lack of incentives. Manure application has received minimal favour too due to diminishing animal population. This study sought to evaluate the potential of newly developed early maturing and high yielding pigeonpea varieties to supply nitrogen and improve the productivity of low-input agriculture prevalent in semi-arid Kenya, and Africa in general.Specifically,the study sought to: (1) quantify the amount of biologically fixed N_2 by pigeonpea under dominant maize-pigeonpea cropping systems, (2) evaluate the effect of inoculation on N_2fixation, and (3) determine the effect of continuous pigeonpea-maize cropping on maize and pigeonpea yields.The study was conducted for three seasons and had two components: greenhouse experiments to determine the effect of rhizobium inoculation on N_2-fixation and on-station field trials to evaluate the effect of maize-pigeopea cropping systems on N_2-fixation. Nitrogen fixation was determined using the isotope dilution technique. Plant samples were analyzed for N and N-15 using the Kjedahl method and mass spectrometry, respectively.Intercropping cereals with short duration pigeonpea varieties depressed both pigeonpea grain and N yield. However,it increased maize yields several-folds compared to the 500 kg/ha usually produced by most farmers. The three dominant pigeonpea varieties(Mbaazi I, KAT 60/8 & Mbaazi II) were found to be generally good fixers, irrespective of the cropping system. The amount of N-fixed ranged from 75 to 87%. Innoculation increased N-fixation in the medium(KAT 60/8) and long duration (Mbaazi II) varieties, but marginally.The two varieties registered a 5% increase in N-fixed as a result of innoculation with KFR 269. Thus, pigeonpea cropping systems have the potential to improve soil N and increase crop yields in Africa. However, this will only be possible if farmers plough back the pigeonpea residues and litter rather than harvesting and carrying away everything from the farm as is the norm currently.

Understanding the dynamics of agricultural technology adoption: Integrated Soil Fertility Management in South Kivu, DR Congo.

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The adoption of new agricultural technologies by smallholder farmers is still a pertinent question for academics and policy-makers. Relatively little is known about technology adoption in the poorest countries and about the adoption of composite technology packages. In this paper we analyze the adoption of Integrated Soil Fertility Management (ISFM) practices by smallholder farmers in South Kivu, DR Congo, after the introduction of these techniques by the Consortium for Improving Agricultural-based Livelihoods in Central Africa (CIALCA). ISFM is a complex technology including the simultaneous use of improved germplasm, judicious chemical fertilizer application and organic matter management.We use original data from a farm-household survey among 450 households, conducted in the period February - June 2011 in two different territories in South-Kivu. We specifically model consecutive steps in farmers' adoption decisions as factors might differently affect the tryout of a new technology and the sustained adoption of it. We model technology adoption as a three step process including awareness, tryout and sustained adoption. By specifying awareness as the first step in the adoption process, we explicitly account for selection bias caused by non-exposure. In addition, we explicitly model the adoption of different components of ISFM. We use a combination of probit and Heckman selection models.We find that awareness rates are higher for improved germplasm (84%) and organic matter management (73%) compared to chemical fertilizer (57%). Tryout rates range between 57% and 8% for different components but adoption rates are quite low (36% to 4%). Membership of farmers' associations and CIALCA presence in the village increase the likelihood of farmers to be aware, test and adopt ISFM technologies. Farm size has no major impact, but farmers renting a larger share of their plots have a higher likelihood of testing and adopting chemical fertilizer and improved germplasm. Land fertility is found to decrease the application of organic matter management and increase the adoption of chemical fertilizer. Access to off-farm income, livestock and non-land asset ownership significantly increase the likelihood of adoption of all components (with the largest effect for chemical fertilizer), which points to the importance of cash constraints.

Using choice experiments for ex-ante assessment of ISFM adoption: an application to climbing beans in Burundi

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Improved soil fertility management (ISFM) is seen as fundamental to improve the sustainability of smallholder agriculture, increase agricultural production, and alleviate food insecurity and poverty among smallholder farmers in developing countries. Various ISFM technologies have been developed, with ample evidence of a positive impact of these technologies on soil fertility and yields. Yet, adoption among smallholder farmers remains poor. ISFM techniques are often well adapted to local agro-ecological conditions, but not to the local socio-economic and institutional context.Many scientific studies have analysed the factors that influence the adoption of improved agricultural technologies and have stressed the importance of biophysical characteristics, resource endowments as well as market incentives, risk and uncertainty, and household preferences. Most of these studies analyse the technology adoption decision of farm households ex post, after ISFM programs have been implemented. Choice experiments can provide ex ante information on the likelihood of adoption for different types of households, different component and features of ISFM techniques, and different extension methods. Such ex ante research is useful for refining programs before they are implemented or out scaled because it gives insights into which components of ISFM to promote, which households to target, and which complementary support measure to set up.We used choice experiments to study preferences and constraints for adoption of improved climbing beans in Burundi. During focus group discussions and expert meetings five major characteristics where identified for further exploration in the choice experiments: 1/ yields without fertilizer use, 2/ yields with chemical fertilizer application, 3/ improved soil fertility, resulting in higher yields for rotating crops, 4/ the maturation period, and 5/ the price of the seeds. For each attribute, three levels were distinguished. A fractional factorial design was used to generate 27 choice cards, splitted in three sets of 9 choice cards. On each choice card the farmer faced two alternatives. A random distributed sample of 200 farmers was interviewed in Gitega province leading to a total of 3600 choice observations. The choice questions were accompanied by a complementary socio-economic household survey.Data were analysed using conditional and mixed logit models. The results indicate that better yields of climbing beans, with or without mineral fertilizer application, and better yields of rotating crops due to increased soil fertility, are the most important attributes in farmers' adoption decision. When distinguishing between different types of households, we find that severely food insecure farmers have a lower willingness to pay for future increases in productivity, and a higher preference for early maturation of the beans. Farmers in a better food security situation have no preferences for maturation period, and a higher willingness to pay for improved soil fertility and future crop productivity.

Production of plant growth regulators and crop yield promotion by phosphate rock solubilizing strains of *Bacillus*

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Universal methods of detection and determination of plant growth regulators have been developed using the high affinity of Siderophores for iron (III), ferric chloride test and sulphuric acid for Indole Acetic Acid and the colorimetric method, containing Picric acid and calcium carbonate for Hydrocyanic Acid. Six (6) *Bacillus subtilis* subsp., isolates (I_1, I_2, I_3, I_4, I_5 and I_6) which are rhizosphere bacteria,were submitted to the various tests mentioned above to highlight their ability to produce these substances promoting the growth and production of the crop plants. The tests revealed that all the strains produced Sidérophore, Indole acetic acid and other similar compounds like organic acids, but none produced the Hydrocyanic acid. The number and nature of the four produced low molecular weight organic acids (lactic, gluconic oxalic and succinic acids) were determined by Dr. Murphy's laboratory at Purdue University, Indiana, USA. Beside the ability of these microorganisms to produce plant growth substances, they also can dissolve the Mali Tilemsi phosphate rock (TPR) and make the phosphorus (P) available to the plant by the production of the quoted low molecular weight organic acids. These bacteria in field conditions did not influence maize plant height after 60 days of growwth, but positvely influenced the grains and dry aerial biomass yield and (P) content: 371.5 kg/ha or 12.33% and 296.93 kg/ha or 8.46% for yield and biomass increase vs control, resprctively 0.88 kg/ha or 27.41% and 0.84 kg/ha or 22.58% for (P) content in grains and aerial biomass increase vs control, respectively compared to control. They could be used in agriculture as bio-inoculants through the known advantages of promoting crop plants growth protection and production.

Nitrogen uptake by maize hybrids in soils amended with lime, rock phosphate and farm yard manure

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Field experiments were conducted in the long rain seasons of 2009 and 2010 at the Kenya Agricultural Research Institute, Molo on an acid mollic Andosol to test the effect of lime (L), Minjingu phosphate rock (MPR) and Farm Yard Manure (FYM) on soil available N, uptake of N and maize yields. Two maize hybrids (H513 and H624) were grown. The experiment was laid out in a randomized complete block design with 23 factorial arrangements. The factors each at two levels were lime (0 and 3 t ha^{-1}), MPR (0 and 60 kg P ha^{-1}) and FYM (0 and 5 t ha^{-1}) giving a total of eight treatments; control, L, RP, FYM, L+RP, L+FYM, RP+FYM and L+RP+FYM. Plant and soil samples were collected at seedling, tasseling and cobbing stages of maize growth for total N and soil available N determination. The application of amendments L, MPR and FYM increased soil available N and its

uptake by maize and consequently maize yields. The amendments effect on soil available N and N uptake was pronounced when applied in combination. The maize hybrid, H513 with lower yields is recommended for planting in view of the changing climate alongside the popular H614.

Assessing the influence of trees on soil macrofauna and soil properties in agricultural landscapes of Tanzania

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Trees in farmlands contribute to soil organic matter levels through leaf litter additions and root turnover. Trees also play important roles in the improvement of nutrient cycling and a more efficient utilization of existing soil nutrients as well as those externally applied. Soil macrofauna distribution is influenced by spatial variability of organic resources as they are influenced by land use and climate. There is limited information available on the effect of trees on the spatial distribution of soil macrofauna activity in agricultural landscapes. This study was therefore undertaken to understand the influence of indigenous trees on soil macrofauna as related to changes in soil physical and chemical properties. The soil macrofauna study was conducted at the Kiberashi Sentinel Site, Tanzania (AfSIS), following the LDSF nested sampling design across a total area of 100 square kilometers. A total of six-hundred and forty (640) monoliths (25 x 25 x 10 cm) were collected, soil macrofauna separated by hand sorting, and soil samples prepared for spectroscopic analyses. Organisms were not identified to species and only the main taxa were considered. In the lab, organisms were separated into seven broad groups (earthworms, termites, ants, beetles, millipedes, centipedes and "other invertebrates"). Density and biomass of each of these groups were determined in each of the soil monoliths. Mid-Infrared (MIR) Spectroscopic analyses and soil textural analysis were used to characterize monolith soils inhabited by soil macrofauna. Earthworms, centipedes, millipedes and beetles showed significant clustering, while termites and ants did not. Moisture conditions influenced the distribution of earthworms and millipedes. Soil total C, pH, available P, clay content and exchangeable bases explained close to 80% of the variation in soil properties. High abundance of earthworms, centipedes and millipedes and lower abundance of beetles were found in soils of higher pH, while higher C soils had high abundance of earthworms and lower abundance of termites and millipedes. Higher abundance of termites was found in soils with high clay content.

Effect of fertilizer micro-dosing on yields of intercropped maize and pigeonpea in Tanzania

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Declining soil fertility, land degradation and poor seed are the fundamental biophysical constraints to increasing food productivity and therefore per capita food production and incomes in Africa. The average amount of fertilizer used in Tanzania is low (7-9 kg/ha). Maize yield under farmers' conditions is low (0.8 to 1 MT/ha.). Pigeon pea yield under farmers' conditions is also low (300 to 400 kg/ha); compared to attainable yields of about 3 MT/ha under improved management. Pigeon pea is able to biologically fix nitrogen (BNF), and seasonal estimates range between 40 and 120 kg N ha^{-1}. However, the amount of residual N left in the soil after harvest, is not adequate for the intercropped maize in the succeeding season. Productivity can be increased through supplemental application of P–based fertilizer to both maize and pigeon pea. A trial was conducted during the long rains in 2009/2010 and 2010/2011 seasons using a total of 160 Mother demos to determine the effect of P fertilizer micro-dosing on the yield and net benefits of maize and pigeon peas intercropping. Pigeon peas yield from the DAP micro-dosing was significantly higher than the control ($\rho \leq 0.05$). The maize and pigeon peas grain yields obtained from the fertilizer micro-dosing treatments were almost double the amounts obtained from the control treatment. The DAP treatment produced higher maize and pigeon peas yields compared to the other micro-dosing treatments. Net benefits obtained from the maize pigeon peas intercropping with micro-dosing were significantly higher than those obtained from sole maize. The cost benefit ratio from the maize pigeon peas intercropping with micro-dosing ranged from 1.8 to 2.2 whereas the sole maize fertilized and control had 1.1and 1.4 cost benefit ratios respectively. The DAP treatment had the highest cost benefit ratio. The sole maize had lower net benefit than maize pigeon peas intercropping without fertilizer, which encourages intercropping of cereals with legumes.

Factors influencing ISFM knowledge in the Central Highlands of Kenya

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Soil nutrient depletion is one of the major biophysical constraints affecting agricultural production in sub-Saharan Africa. Despite past research developing soil fertility management options, few of the recommendations from this research have been put into use by the targeted endusers mainly due to low levels of knowledge and understanding about these technologies. This study attempted to identify the knowledge levels of the farmers and the socioeconomic factors influencing the levels of knowledge for effective and enhanced uptake and utilization of these technologies in Meru South, Maara and Mbeere South districts of the central highlands of Kenya where 300 farmers were randomly selected. It has been observed that, 75% of the respondents in the study area had high levels of knowledge in use of manure, 73% of the respondents had high levels of knowledgeon the use of fertilizers while 43% of the respondents had moderate levels of knowledgein the use of manure +

fertilizers. A Logistic regression model identified age of the household head (HHH), training in the use of animal manure and group membership to significantly influencehousehold levels of knowledge in use of animal manure. On knowledge in the use of fertilizers, a Logistic regression model identified group membership, age of the HHH and total farm size to significantly influence the levels of knowledge in inorganic fertilizers. In regard to the use of manure + fertilizers, a Logistic regression model identified gender of the HHH, household size, training on manure + fertilizers, group membership and total farm size to significantly influence the levels of knowledge in manure + fertilizers at $P<0.05$. The implication of these results is that in order to improve knowledge levels, training should be enhanced and targeted to the farmers belonging to farmer groups considering their gender, age and total farms size.

Coppicing tree legumes intercropped with maize for improved crop productivity and weed management on a clay soil in north-eastern Zimbabwe

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Despite continued research efforts to avail alternative environmentally friendly and low cost technologies for the supply of nitrogen (N) to the staple maize crop, Zimbabwean smallholder farmers continue to produce < 0.5 Mg grain ha^{-1}. A study was conducted between 2007 and 2009 to determine the effect of intercropping coppicing tree legumes with maize on soil N capital, weeds and crop productivity. Maize intercropped with two coppicing agroforestry tree species (*Acacia angustissima* (M-AA) and *Gliricidium sepium* (M-GS)) were compared with maize–soybean (M-S) intercrop and sole cropped maize (S-CM). During the first cropping season, S-CM had a significantly ($p< 0.05$) higher growth rate than intercrops as indicated by plant height (50.5 cm) and leaf area (593 cm^2) at 4 weeks after planting (WAP), which were 50–90% above the grain and tree legume intercrops. At 12 WAP, legume biomass productivity was in the order: *A. anguistissima>Glycine max>G. sepium*, and strongly correlated with total soil N determined at 12 weeks after crop harvesting. Dominant weed species included *Commelina benghalensis*, *Richardia scabra*, *Rottboellia cochinchinensis* and *Cyperus rotundus*, while minor species were mainly broadleaved, but there were no significant differences in weed population for all treatments. During the first season, maize intercropped with *A. angustissima* produced 70% more grain than the M-GS treatment which yielded only 1.2 Mg ha^{-1}, while the S-CM treatment gave superior yields of up to 2.7 Mg ha^{-1}. Overall, M-AA treatment produced significantly ($p< 0.05$) higher maize grain than the rest of the treatments reaching up to 3.4 Mg ha^{-1}, in the second cropping season. We concluded that, even on relatively fertile soils, maize–legume intercropping enhances soil N capital build-up if sufficient biomass is generated, although yield benefits are realized after at least one season, without any effect on weed management.

Promoting Integrated Soil Fertility Management within grassroots NGOs

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Alex Magaga was unable to attend this conference due to his untimely death on 18 September 2012. Alex was founder of the Hagonglo CBO in west Kenya and a pioneer in Research for Development. The following serves as a tribute to his work

ISFM empowers farming households to wiser decisions concerning crop enterprise and resource management on daily basis. Capacity building begins with farm households and extends to rural development specialists and policy makers that are presumably working on behalf of the agricultural community. Soil fertility management requires that different actors expert in different fields participate within interdisciplinary settings and constructively interact with experts from other fields. Leaders within the rural community, including local NGOs, must set positive examples for others by adopting and promoting needed technologies and new enterprise. Neighbouring farmers and groups share common problems and solutions and therefore can organize for collective action. A large number of farmer self-help groups commonly arise to; better access information, learn new low-cost technologies, and pool resources to acquire or to market surpluses. These grassroots organizations consolidate into wider umbrella organizations into wider umbrella organizations to broaden the scope of their services. Farmers that have joined these movements expect; better access to and more reliable information, strengthened capacities for adaptive research, particularly in the areas of soil fertility management, pest and disease control and better access to and lower costs for key agricultural inputs particularly improved seed and fertilizers and improved access to higher end-buyers to market their crop surpluses. These four expectations are not independent of one another, but represent an orderly progression.All capacity building actions must take into account the provision of broader services particularly; farmers improved access to technologies, farm inputs and commodity markets and their expectations of improved living standards. The farm association officials elected should be early adopters of numerous promising technologies and their farms should serve as neighbourhood models of mixed enterprise agriculture. An expedient means of dissemination is to contract farmer associations to install field demonstrations using technology packages accompanied with protocols. Association members are encouraged to install one or more but also encouraged to modify them or include other practices. The demonstrations should be monitored and the most successful of them upgraded to full farmer field days. Targeting technology demonstrations or community field days to schools allow for large number of farmers to be mobilized by their own and neighbouring children and for teachers and administrators to provide peer support and professional expertise to recommended farm practices. Extension officers are obvious clients for capacity building in ISFM. Larger NGOs should incorporate their principles into their development activities and the smaller CBOs to form around them. The NGOs should play the role of training of trainers involving the development of master farmer programs. They should launch these programs by providing candidate farmers with the information and tools necessary to instruct others in different farm activities and enterprises.

ISFM use in bean production in Southern Africa: The role of social and human capital

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Many African households will continue to rely on agriculture for the foreseeable future. However, growth of the agriculture sector is being compromised by continual soil fertility mining, leading to unsustainable agriculture production, as the inherent soil fertility is no longer capable of supporting crop growth at a rate that is required to feed the growing population. This threatens food production which is the major income component for the majority of rural households in most parts of Africa. This calls for concerted efforts to promote smallholder soil fertility management using relatively more sustainable options such as integrated soil fertility management (ISFM), particularly incorporation of grain legumes and inorganic fertilizer in maize production systems. Many studies in Malawi concentrated on the main staple food crop, maize and left out the most significant legume crops as far as ISFM is concerned; beans. Beans are a very important crop in enriching the soils with nitrogen and they are the main source of plant protean for many Malawians hence widely grown in the country. In this paper we analyse the factors that influence bean productivity among smallholder farmers given the commonly used ISFM technologies in Malawi namely, use of animal manure, organic fertilisers, mulching and use of foliar fertilisers. The paper used a multiple regression model to establish the effects of ISFM technologies on bean yields in Malawi. Using purposeful and simple random sampling techniques, a total of 214 smallholder bean farmers were sampled and interviewed. Multiple regression analyses were used to establish the relationship between bean yields and the ISFM technologies used in production. Results indicated that farmers were applying an average of 191 kg of manure, 23.8 kg of DAP, 24.4 kg of urea and 0.39 kg of foliar fertilisers to beans. Regression analysis results indicated that there was a positive and significant ($P<0.05$) relationship between bean yields and manure application as well as foliar fertilisers. Nevertheless, there was no significant ($P>0.05$) relationship between bean yields and organic fertiliser application. This may be so because many farmers do not apply organic fertiliser to beans unless if grown in intercrop with maize. Hence, having majority applying manure to bean fields. It was further established that use of fertilisers on bean fields was influenced by levels of social and human capital and farmers' perceptions of effect of fertilizers on soil fertility. Farmers who perceived fertilizers as bad for bean production were less likely to use them on beans. This is a key result as the emerging discussion on ISFM use for a green revolution for Africa, as well as, the continued food crisis discussion is prompting increased ISFM use as an immediate intervention for increasing food production in the region. The results show that there is need for increased efforts in evolving farmer's perceptions and attitudes towards fertiliser use in beans this can result in double combinations of restoring soil fertility.

Soil fertility management strategies for priority crops in Machakos and Bungoma

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Agriculture is affected by and contributes to climate change. Smallholder farmers, who form the majority of agricultural producers in Kenya, are largely vulnerable due to the change in climate. Empirical evidence has shown that farmers can adapt to climate change by using sustainable land and water management (SLWM) practices that provide local mitigation benefits, reducing or offsetting the negative effects of climate change at plot, farm, or even landscape levels. The objective of this study was to understand farmers' soil fertility management strategies for priority seed propagated crops in the face of changing climate, as a basis for disseminating relevant sustainable land management practices. This study focused on two contrasting agro-ecosystems; the semi-arid Mwala district, Machakos county and sub-humid Bungoma County, both characterized by degraded and degrading soils. Household surveys were conducted in each of the study areas with 90 and 77 respondents in Bungoma and Machakos Counties respectively. To analyze farmers' perceptions of, and adaptation to climate change, the multinomial logit (MNL) model was used. The MNL model is commonly used in adoption decision studies involving multiple choices to assess individual level choice. From the results, actions that would affect soil fertility management as an adaptation option were analyzed. Land area, distance to input market and access to credit all had a significant relationship (at 5% level of significance) with use of soil fertility management techniques. The surveyed farm households were primarily mixed crop-livestock producers, with maize and beans being the most important crop. Cowpeas, and greengrams in Machakos and groundnuts in Bungoma were the next priority seed propagated crops that were used in the analysis. Average land sizes, though not symmetrically distributed amongst households in each study County, averaged 1.55 ha and 1.22 ha in Bungoma and Machakos Counties respectively. At least 63% and 28% of respondents in Bungoma and Machakos applied fertilizer on maize at varying rates. Application rates of organic sources was significantly different in the two Counties. None of the farmers interviewed in Bungoma apply inorganic fertilizer on pulses and groundnuts while at least 29% in Machakos do. Agronomic measures practiced to increase nutrient retention on farm include organic fertilizer application (38%), intercropping (14% Bungoma and 35% Mwala). Cover cropping was practiced in Bungoma (16%). At least 13% and 5% of respondents in Bungoma and Machakos indicated that in response to the changing climate, they adapted by adjusting their fertilizer application patterns through combining organic and inorganic sources, adjusting fertilizer application rates and targeting high value crops. The study results show that with decreasing distance from input markets, where farmers can purchase inputs or implements, farmers are more likely to adopt soil fertility management techniques as they are easily accessible within the farm and the village. Adoption of sustainable soil fertility management strategies remains low among the study farmers and hence an opportunity for the implementers to seek participatory approaches that will increase adoption, preferably by targeting crops that are of economic significance to the study areas.

Impact assessment of soybean processing and marketing by Soybean Resource Centers in western Kenya

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Due to soybean's high protein content (40%), its potential market value, and its ability for improving the soil N balance, soybean (*Glycine max* L. Merr.) has a vital role to play to improve farmer livelihoods in East Africa, especially in areas with high levels of poverty and protein energy malnutrition. Biological nitrogen fixation by promiscuous soybean cultivars also presents a potential for minimizing the investment made by resource-poor farmers on nitrogen fertilizers. Soybean Resource Centers (SRCs) are soybean production and marketing promotion centers formed nearly six years ago in Western Kenya by local farmer groups and multiple stakeholders, facilitated by TSBF-CIAT in the context of the Tropical Legumes II (TL-II) project. After SRC establishment, it was necessary to evaluate their performance, impact, as well as their future prospects. The study was focused on 3 SRCs in western Kenya : (i) MUDIFESOF (Mumias District Federation of Soybean Farmers), located in Mumias district; (ii) BUFESOFAG (Butere District Federation of Farmers' Groups), located in Butere district, and (iii) UFCS (Uriri Farmers Co-operative Society), located in Migori district. Data on SRCs was collected by questionnaires administered to SRC officials, farmers, as well as direct observations of SRC facilities. The objectives of the study included the following: i) assessment of the quality of SRC facilities and business records, ii) comparison of SRC profitability and turnover, iii) assessment of SRC product processing, iv) and to determine SRC impact and future prospects according to SRC officials and farmers. MUDIFESOF turned out to be the most important, active, productive, growing, viable, and effective SRC, while UFCS showed the least performance trends across most evaluation criteria. Despite the low UFCS performance, UFCS achieved reasonable successes in farmer training and outreach arising from an aggressive approach to dissemination. Meanwhile, MUDIFESOF recorded the most amounts of benefits and impacts that were experienced by farmers. Being the best equipped and staffed SRC, MUDIFESOF recorded the highest production surplus and the least production deficits. The success rate in implementation of activities was clearer in MUDIFESOF, growing annually. The annual success rate of MUDIFESOF grew in tandem with the farm area under soybean and yearly farm-level soybean profits. MUDIFESOF also showed the largest growth in staff, products, innovations, and farmer base. In terms of economic performance, MUDIFESOF also registered good product BCRs, economic efficiency and technical efficiency. SRCs made profits selling soybean and soybean-related products, although they were variable and modest. The survey showed that there was potential to increase profits, but this will require further increases in traded soybean volumes arising from increased production, soybean awareness creation, and strengthening soybean market linkages. Although the SRCs made moderate profits, the SRC impact, viability, and community relevance was substantive.

Evaluating the perfomance of selected commercial bio-fertilizers on soybean production in Bungoma, Kenya

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In Western Kenya, mixed cropping, with minimal nutrient inputs are the norm and crop rotation is secondary to continuous maize cropping. Too few farmers recognize the benefit of improved soil fertility through nutrient recycling. Leguminous intercrops and short fallows contribute nitrogen to the soils through biological nitrogen fixation, but this process and root nodulation is not widely recognized as beneficial by farmers. Productivity of soybeans in Kenya, and particularly Western province, is low (450 kg/ha) compared with Brazil and USA. The reasons for poor production in Western Kenya have been clearly identified as absence of desirable traits such as tolerance to extreme temperatures, high yields, resistance to soybean mosaic disease and tolerance to acid soils. With increasing fuel prices, the cost of mineral fertilizer is arising (currently some 450 pounds per ton of N from urea), making it less available to small-scale farmers. The objective of the study was to evaluate the inoculants under smallholder farms hence improve soil nutrient status in the region and the overall food production through the use of promiscuous soybean variety. The trials were laid out on farms in Bungoma (latitude 000 34, N and longitude 340 34, E).The experiment was established during the long rains (LR) and repeated during the short rains (SR) of 2010, laid out in multi-locational trials. Treatments were not replicated within each field: instead, farmer groups per site and season were considered as replicates. A promiscuous medium-maturity soybean variety TGx1740-2E (SB 19) was inoculated with either or both inoculants and planted at 50 cm between rows and 7.5 cm between plants in the rows. Each experimental plot had nine rows. Rhizobial inoculation was done by thoroughly mixing 125 g of damp seed with 2 g of inoculum (1×10^{-9} CFU g^{-1}). The mycorrhizal inoculum was applied to the soil in the seed furrows at the recommended rate of 30 kg ha^{-1}. Nodulation was examined at mid-podding by carefully uprooting all plants with their entire root system from a 1 m^2 section in each plot. Analysis of variance was conducted to determine the effects of (and interactions between) the two inoculants on plant parameters using a mixed linear model. The effects of different treatments were compared by computing standard error of difference (SED). Rhizobial inoculation resulted in significantly ($p<0.01$) higher nodulation (0.93 g $plant^{-1}$) compared to the control (0.27 g $plant^{-1}$). Mycorrhizal inoculation had no significant effect on nodulation when applied solely (0.38 g $plant^{-1}$), but co-inoculation of rhizobia and mycorrhiza increased nodulation further by 0.09 g $plant^{-1}$. There was significant difference ($p<0.01$) in terms of biomass yield between treatments. Rhizobia inoculant had the highest biomass production at (2086 kg/ha). Rhizobial inoculation resulted in higher grain yields (1116 kg/ha) and there was no significant difference between sole application of rhizobial (1116 kg/ha) and the co-inoculation (1027 kg/ha) at $p<0.01$ but there was significance difference between Rhizobial and the control (924 kg/ha). Rhizobial inoculants have a high potential as commercial bio-fertilizers. However, there is need to target these inputs to the most responsive fields for maximal economic benefits. Further studies are needed to elucidate the conditions under which synergism between both inoculants may occur.

Agroforestry: an alternative candidate soil fertility paradigm in west Kenya

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This paper explores from a social science perspective the available evidence that agro-forestry can be a second soil fertility paradigm. The data for this paper is derived from a range of studies done in Western Kenya, notably in Siaya district. Farmers in this region generally do not apply fertiliser. A review of the quantitative and qualitative data indicates that such an answer is not unequivocal. The detailed case studies of certain homesteads in the region show that people are convinced agro-forestry helps to replenish soil fertility and that over the years, yields indeed have increased. Even though there is evidence of relative success of the Green Revolution in increasing food production, many argue that intensive packages of improved varieties and fertiliser should be widely applied as the model for agricultural development and as a means of ensuring household and national food security. Although this sounds appealing, this paper shows that there are numerous constraints that curtail adoption of this approach in Western Kenya. The high price of commercial fertilisers heightens the urgency of the search for alternatives. Scientists recognise that lowering the costs of restoring fertility is vital to the future of agriculture in the region. But aside from the cost argument, there are other good reasons for diversifying farmers' soil fertility options. In a region like Western Kenya, nutrient and other soil constraints are multiple. That means farmers need a cocktail of techniques in which synergies can occur. Also, farmers face multiple socio-economic constraints (finance, labour, land) each of which favours different types of soil fertility options. On both counts, commercial fertiliser alone is clearly not the answer. Low-cost technologies and practices for supplying nutrients to crops are needed on a scale wide enough to improve the livelihood of farmers. In this paper, we have analysed alternative and practical approaches of increasing domestic food production using improved fallows with *Sesbania sesban*, *Crotalaria grahamiana* and *Tephrosia vogelii* and also through the use of green biomass manure transfer from the prunings of the shrub *Tithonia diversifolia*. This approach builds upon farmers' traditional production strategies and on collaborative national and international research efforts and represents regime change 'from within' and 'from below'.

Zinc fertilization, maize productivity and grain quality under integrated soil fertility management in smallholder farming

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Soil fertility management research efforts to increase productivity of staple cereal crops in sub-Saharan Africa have paid little attention to soil micronutrient deficiencies under smallholder farming. A study was carried out in Wedza District in eastern Zimbabwe during the 2009/10 and 2010/11 season to investigate the additional maize (*Zea mays* L.) grain yield value of zinc (Zn) fertilizer application under integrated soil fertility management options. Results showed that Zn had an added grain yield benefit to both sole mineral and mineral and organic fertilizer combinations. Combinations of organic and mineral NPK and Zn fertilizers resulted in superior grain yields. In the first cropping season (2009/10), co-application of leaf litter at 5 t ha^{-1} with mineral fertilizers produced 3.9 t ha^{-1}; translating to 1.3 times more yields than attained under sole mineral fertilizers (90 kg N ha^{-1} and 26 kg P ha^{-1}). In the subsequent season, residual organic fertility gave 2 t ha^{-1} more grain yields than sole mineral fertilizers. Zinc application resulted in a significant increase in grain Zn concentration under both sole mineral fertilizers and combinations. Consistently, maize grain under combination of mineral NPK and Zn and leaf litter gave the highest grain Zn concentration of up to 33 mg kg^{-1}. An increase of 67% in grain Zn concentration against a 29% increase in yield in the sole mineral fertilizer treatment showed that there was much more benefit in grain quality than yield after external Zn application. Apparently, treatments without Zn fertilizer produced the highest P concentration of up to 0.33% compared with Zn fertilized treatments (<0.25% P). Phosphorus and Zn fertilization resulted in appreciable build up of soil available P and ethylenediaminetetraacetic acid (EDTA) extractable Zn of 6.5 mg kg^{-1} and 5.4 mg kg^{-1}, respectively from 5.2 mg P kg^{-1} and 1.15 mg Zn kg^{-1}. Benefits of ISFM options as currently presented to smallholder farmers are likely to be enhanced by Zn application.

Diversite et nodilation des legumineuses sauvages de la foret equatoriale

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Les légumineuses sauvages se trouvant dans l'axe Djolu-Lingomo et Lingomo-Bomwankoy situés respectivement dans le territoire de Djolu et Befale en RD Congo du 25 mai au 25 juin 2011 ont été étudiées. Un accent particulier a été mis sur la fixation de l'azote sur base de la présence des nodules par ces légumineuses dans différente utilisation de terre à savoir les forêts primaires, forêts secondaires, les jachères comprises entre 5 à 10 ans et les jachères comprises entre 0 à 5 ans. Dans ces différentes utilisations de terre les méthodes de transect dans lesquelles étaient inclus la méthode de placeaux circulaires, ainsi que la méthode de déracinement des individus de chaque espèce de légumineuse pour voir la présence des nodules à été utilisé.Nous avions effectués les inventaires dans chaque type d'utilisation de terre et ses inventaires étaient effectués en trois répétitions. Chaque transect avait 0,1 hectare. Cette étude a révélé que cette contrée engorge une végétation très riche en légumineuses, nous avions trouvé :Dans la forêt primaire : 963 individus de légumineuses par ha. Ces individus sont répartis dans 16 espèces, tous ces individus n'avaient pas de nodule (ne fixait l'azote). Dans les formations secondaires: 1187 individus de légumineuses par hectare et réparties en 14 espèces. 10 individus seulement avaient des nodules (Fixaient l'azote).Dans les jachères de 5 à 10 ans: 1240 individus de légumineuses par hectare et réparties en 19 espèces. 140 individus possédaient des

nodules. Dans les jachères de 0 à 5 ans : 3007 individus de légumineuses par hectare et sont répartis dans 21 espèces. 1930 individus possédaient des nodules soit 64,19% des individus des ces légumineuse.Les différents indices de diversités ont montré que: Dans l'axe Djolu-Lingomo, ce sont les jachères de 5 à 10 ans qui sont plus diversifiées en légumineuses puis viennent les jachères de 0 à 5 ans. Dans l'axe Lingomo-Bomwankoy les résultats ont montré que ce sont les forêts primaires qui sont plus diversifiées ensuite viennent les jachères de 5 à 10 ans puis de 0 à 5 ans. Pour ce qui est de la diversité de nodulation de ces légumineuses dans les deux axes ce sont les jachères de 0 à 5 ans qui sont plus diversifiées.

The Learning Centre: A new approach to participatory technology development and dissemination in agriculture and natural resource management

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Poor uptake of improved agricultural technologies and better farming practices has remained a major developmental concern in sub-Saharan Africa. The continent's predominantly rain-fed agricultural systems are faced with threats of a rapidly diminishing natural resource base, marked by declining soil fertility and failing yields for staple crops. This is aggravated by increasing rainfall variability associated with climate change. Research and development efforts to address these problems through promotion of new agricultural technologies have been faced with numerous challenges. These include poor targeting of technologies to potential beneficiaries, lack of ownership of the technology development processes and insensitivity to the different pathways through which different categories of farmers access information and knowledge. This paper introduces a new concept of field-based Farmer Learning Centres as a suitable approach for promoting complex agricultural technologies. Examples are given to illustrate how the approach has promoted uptake of different integrated soil fertility management technology options by farmers of different resource endowments. The approach emphasises on farmer adaptive experimentation, non-linear and interactive information and knowledge sharing among farmers and service providers. Key attributes of the approach are also discussed in comparison with some of the approaches commonly employed in agriculture to promote improved management practices and technologies such as farmer field schools. We conclude that the Learning Centre approach provides greater scope for building capacity of farmers to adapt new technologies and generate options that best-fit their socio-ecological circumstances.

Maize response to mineral N, P, K, manure and lime amendments in acid soils of the highlands of Central Burundi

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Traditional farming systems in Sub-Saharan Africa depend primarily on mining soil nutrients. Farmers use limited amounts of organic manure, but rarely apply mineral fertilizer. There are no clear recommendations on the use of inputs for sustainable crop production, while soil degradation progresses at an alarming rate. A multi-locational field study was conducted in 40 farmers' fields across 4 locations in the Gitega province of Burundi to evaluate the response of maize and soybean to application of mineral N, P and K and to addition of lime and manure. The average grain yield obtained at full fertilizer rates with 60 kg N, 90 kg P_2O_5 and 30 kg K_2O ha^{-1} combined with lime at 2.5 t ha^{-1} equalled 2.5 Mg ha^{-1} but varied widely between 0 and 6.3 t ha^{-1}, while control yields (with lime application only) varied between the same range but equalled on average 1.6 Mg ha^{-1}. Omission of P resulted in the largest yield losses (on average 37%), followed by K (11%) and N (2%). Omission of lime, or doubling the lime rate generally did not affect yields. Highest yields were however obtained when fertilizer application was combined with addition of 5 Mg ha^{-1} of farm yard manure, and when yields with sole fertilizer were less than 3 Mg ha^{-1}, yield increases of on average 45% were obtained. These results demonstrate the need for P application and the use of organic inputs for soil fertility management and maize production in the region. Also, since yield levels and responses varied widely, there is need for locally adapted, and site specific recommendations to ensure maximal returns to investment of mineral and organic inputs used. Further study is required to relate responses to inputs with soil characteristics.

The potential of maize-cowpea intercrops to increase crop productivity under reduced tillage in the semi-arid areas of Zimbabwe

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Crop rotation has not been practiced successfully by smallholder farmers in Zimbabwe owing to their small land holdings, dedicated mainly to staple cereal crops, and poorly developed legume markets. Maize- (*Zea mays* L.) cowpea (*Vigna unguiculata* L. Walp.) intercropping trials with two spatial arrangements were established on-station and on 40 smallholder farms to determine effect on grain yield compared to sole crops under semi-arid conditions in Zimbabwe. Maize was planted with the first rains under hand-hoe basin based minimum tillage and cowpea was planted two weeks later either in the same planting basin as maize, in rows between the maize rows or as sole stands at plant populations of 37,000 and 60,000 plants per hectare for maize and cowpea respectively. A basal compound fertilizer (7% N:6% P:6% K) was annually applied at 200 kg ha^{-1} for maize and 150 kg ha^{-1} for cowpea, and maize was further annually top-dressed with 80 kg ha^{-1} of ammonium nitrate (34.5% N) at 4-6 weeks

after planting depending on rainfall distribution in both sole and intercrops. Maize yields were significantly highest ($P < 0.05$) when maize and cowpeas were planted in the same basin in on-farm trials with average yields of 2.5 and 3 t ha^{-1} in 2008/9 and 2009/10, respectively. The same intercrop treatment, however, gave the lowest yield of cowpea both on-station (0.10-0.90 t ha^{-1}) and on-farm (0.35-0.65 t ha^{-1}) and this was attributed to increased competition for nutrients and water from the maize crop. In both seasons, the land equivalent ratio (LER) was >1 for the two spatial arrangements implying that there was an advantage in intercropping than planting sole crops. To determine the ideal planting time for cowpeas in the intercrop, the on-station trial was modified in the third and fourth seasons (2010/11 and 2011/12) to include three planting dates for cowpeas (0, 2 and 3 weeks after planting maize). In 2010/12, a relatively wetter season, maize yield (3.7 t ha^{-1}) was highest when cowpea was planted in the same planting basin and at the same time as maize. In the 2011/12 season, which was a drought season, maize yield (av 0.7 t ha^{-1}) was highest when cowpea was planted between the maize rows and three weeks after planting the maize crop. Cowpea yield was highest when the crop was planted in sole stands (0.9 t ha^{-1} in 2010/11 and 0.2 t ha^{-1} in 2011/12). The cowpea yield decreased the later the planting date whether planted as intercrops or as sole stands. It was concluded that intercropping maize and cowpea resulted in yield benefits compared to sole crops. Planting the crops in the same basin, which favoured the staple maize crop, was the best spatial arrangement in wetter seasons but in drought seasons planting separate rows of the two crops was a better option in order to reduce competition for moisture.

Improving maize yield through use of mucuna and lablab at Kibondo and Kasulu districts, western Tanzania

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Crop production in the western zone is declining due to, among other problems, soil exhaustion. Farmers in this area are resource-poor, and are limited to means and access to inputs for soil fertility replenishment. Soil fertility replenishment could be achieved through application of inorganic fertilizers, but major constraint to the use of these inputs is unfavourable price-ratio of inorganic fertilizers to maize crop, which make inorganic fertilizers unaffordable to the majority of the small-scale farmers. Contribution of organic materials to soil fertility replenishment, particularly leguminous plants. is very well documented in science but its practice has not been widely explored. However, small-scale crop production in many parts of Tanzania is constrained by many problems among which soil fertility degradation is a major problem. Over 80% of maize production in Tanzania is done by small-scale farmers who continuously cultivate their fields but use limited inputs to restore depleted plant nutrients. The objective of this study is to identify the best legume species that could be incorporated in maize production systems under farmers' conditions and result in increase in soil fertility and crop yields. The legume treatments were compared with mineral nitrogen levels 0 and 50 kg t/ha. Biomass yield and nitrogen content of the legumes were determined at flowering stage. The effect of of the legumes on soil fertility was determined at flowering stage. Mucuna and lablab were either incorporated with maize or planted as sole crop in rotation with maize. Biomass yield was determined on station, nitrogen content of the leguminous were determined from a sample during flowering stage. Mucuna and lablab were found to produce almost similar amount of biomass. The two legumes, however, produced higher biomass in rotation than intercropping system. The amount of biomass produced by mucuna and lablab in rotation system was 6.28 t/ha and 5.31 t/ha, respectively. Nitrogen content of mucuna and lablab was found to be 2.57 and 2.69% respectively. Rotation and intercropping of maize with mucuna and/or lablab increased maize yield significantly over the control (continuous sole maize) during the second season. On average, they increased maize yield over the control treatment by 118% and 120% under rotation and intercropping systems by 62% and 56%, respectively. Mineral nitrogen fertilizer improved maize grain yield by 87%, which is intermediate to the two cropping systems used for the legumes. Economic analysis following partial budget analysis showed that intercropping maize with mucuna and lablab gave higher benefit than when the two legumes are grown under rotation system. Their net benefits/MRR was obtained when maize was intercropped with the two legumes. Rotation system had the lowest net benefit/MRR because of the maize crop forgone during the first season. From this result it was concluded that the two legumes have almost equal high potential as alternative sources of nitrogen for soil fertility improvement, and they could be useful in increasing maize yield.

Do we really need to inoculate cowpea and green gram with commercial inoculants to improve yield and nitrogen fixation in Kenya?

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Cowpea (*Vigna unguiculata* L. Walp.) and green gram (*Vigna radiata* L.Wilczek.) are important legumes cultivated for their drought tolerance, nitrogen-fixation capacity and nutritional value. Reduced cowpea and green gram yields in Kenya can in part be attributed to declining soil fertility and absence or presence of ineffective indigenous rhizobia, aspects that require further investigation. In this study, soils were collected from legume growing areas of Western (Bungoma), Nyanza (Bondo), Eastern (Isiolo), Central (Meru) and Coast (Kilifi) provinces in Kenya to assess indigenous rhizobia in soils nodulating cowpea and green gram under greenhouse conditions. Our results showed that highest nodule fresh weights of 4.63 and 3.32 g $plant^{-1}$ for cowpea and green gram were observed in one soil from Isiolo and another from Kilifi, respectively suggesting the presence of significant infective indigenous strains in both soils. On the other hand, lowest nodule fresh weights of 2.17 and 0.72 g $plant^{-1}$ were observed in one soil from Bungoma for cowpea and green gram, respectively. Symbiotic N fixation by cowpea and green gram was highest in Kilifi soil with values between 98% and 97%, respectively. Genetic diversity of indigenous strains nodulating both legumes was assayed using Polymerase Chain Reaction (PCR) - Restriction Fragment Length Polymorphism (RFLP) of the 16S-23S rDNA intergenic spacer region (IGS). PCR-RFLP analysis of 271 nodules from both legumes using Msp I revealed nineteen IGS groups I-XIX, with IGS I-X common in both legumes. Predominant IGS groups were I and II

constituting 32.1% and 31.7%, respectively of all nodules analysed. IGS XI-XVI and XVII-XIX were specific to cowpea and green gram, respectively with each constituting less than 2%. A second greenhouse experiment was undertaken to evaluate the performance of commercial rhizobial inoculants with both legumes in Chonyi soil (also from Coast province) containing significant indigenous rhizobia (>13.5 x 10^3 CFU g^{-1}). Results of the first experiment on nodule fresh weight (4.25, 3.32 g $plant^{-1}$), and Ndfa (98% and 97%) in cowpea and green gram, respectively in Coast (Kilifi A) convinced us to select coastal soil from Chonyi. Rhizobial inoculation did not significantly ($P<0.05$) affect nodulation, biomass yield and shoot N content in cowpea and in green gram compared with controls. PCR-RFLP analysis of nodules revealed the existence of six IGS groups of which only one (IGS I) corresponded with those from commercial inoculants applied, indicating a lower competitiveness of inoculated strains. IGS group III was predominant in nodules from both legumes and present in all treatments. In cowpea, IGS III dominated in Biofix, Rizoliq and the uninoculated control (63.2, 60 and 52.9% occupancy, respectively) and in green gram, IGS III dominated in Biofix 704, Rizoliq and in the uninoculated control treatments (75, 73.7 and 61.1%, respectively). Our results suggest that the systematic inoculation of both legumes with current available commercial inoculants to improve biomass yields is not necessary in these regions of Kenya. Also, according to our study, it would make sense to promote the utilization of native strains performing well with both legumes.

Multi-purpose cowpea inoculation for improved yields in smallholder farms in Kenya

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Cowpea (*Vigna unguiculata*) is one of the most important food legumes in Africa. This legume is multipurpose (grains and leaves are consumed), rich in protein and adapted to drought and low nutrients environments. Cowpea derives up to 90% of its Nitrogen requirement from Biological Nitrogen Fixation (BNF) through symbiosis with root nodule bacteria collectively known as rhizobia. In Kenya, cowpea is the most important pulse crop in the dry lands of Eastern and Coastal regions where it is commonly inter cropped with maize and sorghum. The poor yields obtained in small holder farms in Kenya (150 kg/ha) are attributed to the use of poor yielding varieties, low soil fertility (mainly N and P deficiency), pestand disease attacks, low presence of effective indigenous rhizobia and high occurrence of highly competitive but inefficient indigenous strains.BNF through exploitation of the rhizobia-legume symbiosis and use of inoculants coupled with soil amendments such as Phosphorus offers in part a means to improve cowpea yield, nutrition and soil fertility.Previous works in greenhouse conditions have shown that commercial inoculants did not perform as expected because of the low efficacy and competitiveness of the tested strains. This low competitiveness is explained by the occurrence of a high indigenous and competitive population of rhizobial strains in the tested soils. This population represents a huge reservoir of inoculants but contains strains with high and low efficacy and no screening has been performed until now. Also, cowpea breeding programs have so far neglected the traits associated with efficient BNF and no information is available on the molecular and physiological determinants that make cowpea compatible or not to rhizobial strains.This PhD project (to be started in January 2013) intends to; 1) identify competitive and effective rhizobial strains capable of providing sufficient nitrogen derived from BNF for cowpea cultivated in two agro-ecological zones in Kenya, 2) identify optimal cowpea cultivar-rhizobial strain combinations with improved yield and protein content for different growing conditions of small holder farmers in Kenya, 3) develop molecular markers for the evaluation and monitoring of rhizobial inoculation of improved strains, and 4) develop efficient phenotyping assays for large scale screening of cowpea genotypes for improved symbiosis that can be implemented in breeding programs.This will be achieved through rigorous greenhouse screening and field validation of a wide variety of rhizobial strains (isolated from the target zones) and cowpea cultivars in two agro ecologies in Kenya (Kilifi and Mbeere).To evaluate the efficacy of the cowpea-rhizobia symbiosis during screening and field validation, the following parameters will be measured: nodule numbers, nodule biomass, shoot and root biomass and shoot nitrogen content (total and derived from BNF). Identified effective strains will be used for commercial inoculant production and high yielding cowpea cultivars compatible with efficient rhizobial strains will be selected and disseminated to farmers. Molecular work and growth chamber trials will be used for development of strain specific PCR tests for nodule occupancy, strain competitiveness and assessment of BNF related traits in various cowpea genotypes.

Role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farming systems of sub-Saharan Africa

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Sub-Saharan Africa's population is growing exponentially and it has to fulfill its food and nutrition requirements. An attractive strategy for increasing productivity and labour utilization per unit area of available land is to intensify land use. Intercropping is advanced as one of the integrated soil fertility management practices consisting of cultivating two or more crops in the same space at the same time, which have been practiced in past decades and achieved the goals of agriculture. Also, intercropping systems are beneficial to the smallholder farmers in the low-input and/or high-risk environment of the tropics, where intercropping of cereals and legumes is widespread among smallholder farmers due to the ability of the legume to contribute to addressing the problem of declining levels of soil fertility. The principal reasons for smallholder farmers to intercrop are flexibility, profit maximization, risk minimization, soil conservation and improvement of soil fertility, weed, pests and diseases control and balanced nutrition. This is a review paper that explores the role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farms of Africa. The intercropping systems are useful in terms of increasing productivity and profitability, water and radiation use efficiency, control of weeds, pests and diseases. The critical role of biological nitrogen fixation and the amounts of N transferred to associated crops determines the extent of benefits. In

intercropping, land equivalent ratio (LER), benefit cost ratio (BCR) and monetary advantage index (MAI) are used to assess the productivity and its economics of benefits. In this study, the work carried out by various researchers about different intercropping system is discussed, and it would be beneficial to the researchers who are involved in this field.

Effect of maize–soybean intercropping patterns on yields and soil properties in the Central Highlands of Kenya

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In the Central Highlands of Kenya, low soil fertility and inability to replenish it are amongst the major constraints affecting maize productivity and income generating crops, leading to hunger and poverty. The adoption of ISFM technologies such as maize-soybean intercropping system is being promoted as one of the options to address low crop productivity among the farmers. This study aims to: (i) determine the effects of maize-soybean intercropping patterns on yields and N uptake, and soil properties; (ii) determine the effects of different maize-soybean intercropping patterns on light interception and leaf area index (LAI); (iii) quantify the land equivalent ratio (LER) of various maize soybean intercropping patterns; (iv) assess the economics of various maize soybean intercropping patterns. The study areas are Embu – ATC in Embu district and Kamujine in Tigania East district. The main treatments are four maize (M)–soybean (S) intercropping patterns (1M:1S; 2M:2S; 2M:4S; 2M:6S) and two sole crops of maize and soybean, respectively. The experimental design will be a randomized block complete design (RBCD) with four replications. All biophysical data will be subjected to Analysis of Variance (ANOVA) and means separated using Tukey's test ($p=0.05$). The productivity of the intercropping systems will be evaluated using LER, the light intercepted and LAI will be used to assess the radiation use efficiency of different intercropping patterns, and the economic analysis will be carried out through the calculation of Benefit Cost Ratio. This study will contribute on the useful information about optimum maize-soybean intercropping pattern which can guide smallholder farmers on the management of this new cropping system in the region. Further, the study will add value on the ISFM technologies that are being promoted in Africa. Lastly, the study will bring useful information which can guide extension services.

Gender access to formal credit and its impact on micro- and small-enterprises Western Kenya

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Micro- and small-enterprises (MSEs) play an important role in employment generation and poverty reduction in developed and developing countries. In Kenya, the MSEs sector contributed over 50 percent of new jobs created in 2005. However, the development potential of micro- and small-enterprises has not been fully exploited due to lack of access to credit, and lack of adequate support and facilitation. The Kenyan government policy interventions for the micro- and small-enterprises sector through various sessional papers have not yielded the desired outcomes. The objectives of this study were to investigate the factors limiting gender accessibility to formal credit and to determine the impact of formal credit on investments and gender involvement in MSEs in Kakamega municipality, Kenya. Purposive and systematic random sampling methods were used to select the study area and respondents respectively. Two hundred respondents were interviewed using structured qustionnaires, and informants. The study covered the credit programs of commercial banks, non-bank financial institutions and co-operative societies located in Kakamega municipality. Descriptive statistics were used to analyse the data using Statistical Package for Social Scientists (SPSS) and Excel computer programs. The results revealed that 56% of the participants were women while 44% were men. Further analysis indicated that 45.8% had access to credit and only 18.7% were women while 27.1% were men. The results further revealed that access to formal credit had a greater impact (75%) on women operated enterprises than those operated by men (70%). Limited credit institutions, lack of collateral, and high interest limited gender access to formal credit in the MSEs growth.

Improving acidic soils through application of agricultural lime and multi-nutrient fertilizer on smallholder farming systems of Western Kenya

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In western Kenya, the long-term development constraints are 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 beans hardly exceed 0.5 t ha^{-1} $season^{-1}$ on smallholder farms. The declining yields are caused by low soil fertility, soil acidity, use of inappropriate germplasm and high cost of inputs among other constraints. Previous studies indicated that soils in western Kenya were severely depleted of phosphorus (P) and nitrogen (N) in addition to being acidic. The objective of the study was to assess the effects of liming in combination with multi-nutrient fertilizers on soil health and crop yields in Siaya and Kakamega districts of western Kenya. The study was conducted in 24 representative trial farms using a completely randomized block design with six treatments namely lime, diamonium phosphates, Mavuno, lime + diamonium phosphate (DAP), lime + Mavuno and conventional farmers' practice as control. A hybrid maize variety HB 513 was used to evaluate the lime and multi nutrient fertilizers. Soils were sampled every season for chemical analysis to monitor changes in soil characteristics. Overall rating of technologies based on maize yields at harvest was in the preference order of Mavuno, lime + DAP, Mavuno + lime, DAP, lime alone and control last. The soil chemical analysis results showed that most parts of Kabras and Siaya were moderately to strongly acid with pH ranging from

4.63 to 5.81. Liming with multi-nutrient fertilizers were highly appreciated based on the appreciable maize yield increases realized compared to control. The study also revealed that households were medium in size but with high dependency ratio. There were more female headed households with low levels of education. The households were endowed with assets for their livelihoods. However, the level of assets were low or of very poor quality. Maize was the major food crop and source of immediate cash income at harvest but for a very short time. Farmers grew local maize varieties mainly with little improved hybrid ones. Farmers experienced low productivity due to nonuse of adequate fertilizers, as a result of which there was a considerable gap between potential and actual maize yields. The major factors constraining crop production included low soil fertility, acid soils, drought and erratic rainfall.

Upscaling low input smallholder farming systems in rural sub-Saharan Africa

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Soil fertilty depletion in sub-saharn Africa (SSA) is reaching a critical level especially under small farmer holdings. Reduced soil fertilty undermines the production of food, fodder, fuel and fibre. Land degradation in the continent is aggravated by the effects of climate change, population growth and pressure which has led to shrinking land holdings land ownership. Many African soils are heavily depleted of nutrients and soil organic matter is very low below 1.0% or even 0.5% in the top soil. Losses are due to soil erosion, leaching of nutrients, volatilisation of nutrients, and accelerated mineralization of soil organic matter through tillage. Degradation of natural resources in the region is a consequence of rural poverty, resulting from interplay between rising population density, shrinking landholdings and livestock numbers, low technological advances, unreliable markets and weak institutional and policy governance and support in response to emerging challenges. Producing more food for a growing population in the coming decades while at the same time combating poverty and hunger is a huge challenge for a continent with exhausted soils. Due to limited resources most farmers in SSA are forced to grow the same food crops on the same land year after year without adequate fertilization or soil replenishment measures. In order to intensify agricultural productivity in SSA, there is need to invest in revitalizing soil fertility.This article looks in detail a diversity of options available to intensify farm food productivity through investing in pro-poor low inputs systems reliant on recycling of internal organic nutrient resources and water management. The need for incentives from micro finance institutions and capacity building (empowerment the women and youth) are essential.

Soybean performance under different soil characteristics and seed inoculation from commercial products in Bungoma County, Kenya

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Nitrogen and phosphorus are the major nutrients limiting crop production in sub-Saharan Africa leading to food insecurity. Replenishing these nutrients in soils is a major capital investment thus the need for affordable and environmental sound means of improving soil fertility. Technology breakthroughs in soil fertility management have proven that some commercial inoculants (e.g. rhizobial and P bio-inoculants) enhance the productivity of specific legumes such as soybean. This is particularly so in developing countries where commercial fertilizers are costly and unavailable to small scale farmers (like in Bungoma county, western Kenya). On-farm trials were conducted during the 2010 short rains and 2011 long rains to evaluate the effects of selected commercial inoculants on soybean production in Bungoma. Soybean seeds (SB19) were inoculated with different rhizobia inoculants in plots of 4.5 m x 5.0 m. Some treatments received 0, 26 Kg P/ha, 60 Kg N/ha or their combinations. Co-inoculation of most promising rhizobial inoculants (Legumefix) and one of the mycorrhizal/P solubilizing microorganisms inoculants was also evaluated. Experimental treatments were arranged in RCBD design in seven sites. ANOVA was conducted to determine the effects of inoculants on plant parameters using mixed linear model. Effects of different treatments were compared by computing standard error of difference and significance difference evaluated at $p<0.05$. During SR 2010 Legumefix rhizobium inoculant gave significantly ($p < 0.05$) higher nodule fresh weight (1.4 g/plant) and grain yields of 0.53 t/ha compared to control with 0.29 g/plant and 0.32 t/ha during nodulation and harvest, respectively. During long rains 2011 Legumefix, Histick and Rhizoliq-Top 2 inoculants resulted to 182%, 259% and 255% increase in nodule fresh weight /plant, respectively above control. The higher nodulation subsequently resulted to significantly $p<0.05$ higher grain yields than the control. Co-inoculation of legumefix and mycorrhizal/P solubilising microorganism inoculants did not differ significantly (between the treatments) at $p<0.05$ both at nodule assessment and at harvest during the two seasons. However, all the co-inoculated treatments resulted to higher nodulation ($p<0.05$), grain yield and nutrients uptake than the control (sole Legumefix). Among the mycorrhizal inoculants, Rhizatech+Legumefix gave the highest nodulation and grain yield of 1.17g/plant and 0.65t/ha, as compared to the control with 0.91g/plant and 0.46 t/ha respectively, (SR 2010). Rhizatech+Legumefix treatment was found to be superior to all other inoculants during the two seasons. Among P solubilizing microorganism inoculants Myco Tea+Legumefix gave 0.58 t/ha, higher than PHC Biopak+Legumefix (0.54 t/ha) and Subtilex+ Legumefix (0.52 t/ha) during short rains 2010. Overall results showed that use of rhizobial inoculants contributed significantly to soybean production in western Kenya; more positive effect was realised when co-inoculated with AM (Rhizatech) inoculants.

Exploring the effects of different fertilizers on yields and benefits of important crops grown in Kagera, Tanzania

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A study was conducted in Bukoba, Misenyi, Muleba and Bihramulo districts of Kagera region to explore the effect of fertilizers on crop productivity and profitability through application of ISFM technologies and use of improved crop varieties of climbing beans, bush beans, soybeans, cassava and sweet potato. Demonstration fields of different fertilizers with the respective crops were established and managed by individual farmers or group of farmers in different districts. During the whole cropping season, agronomic and socio-economic data were collected by researchers and extension officers. The results showed that there was significant difference ($P \leq 0.001$) in crops response to the application of different types of fertilizers within the treatments and districts but not across the districts. The results showed that application of fertilizers in all the five crops increased grain, root and tuber yields for about 220-530% and biomass yields for about 130-220% as compared to the control. Likewise, the results showed that it is uneconomical to cultivate crops without application of fertilizers. However, further research still needed to determine the optimum fertilizer application rates for optimal crop yields and benefits together with in depth economic analysis including the returns to labour and investment.

Integrating grain legumes in maize-based systems for improved soil healthy, food security and incomes by smallholder farmers in Zambia

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The dominant smallholder agriculture in Zambia is characterized by continuous maize monocropping without addition of external inputs. This system has led to soil nutrient mining thus exacerbating the problem of soil degradation and low crop yields. As a result, farmers get low income from their produce and are more food insecure. The integration of grain legume crops into the continuous maize cropping systems in Zambia has the potential to contribute significantly to national food security through improved soil health and higher crop yields to smallholder farmers. The objective of this study was to demonstrate to farmers the benefits of maize and legume crop rotation farming system, and also of applying chemical fertilizers to legume crops. Grain legume crops (soybean, groundnuts and cowpea) were grown in rotation with maize in 5 districts of Zambia. Fertilizer was also applied as NPK at 0, 6, 12 kg N/ha and 0, 20 and 40 kg P /ha;, and 0, 33 and 66 kg K/ha. Soybean was inoculated in all the plots. Agriculture lime was applied as a broadcast in all the plots at 200 kg/ha. Conservation Agriculture methods of basins or ripping were used in all the plots. Application of fertilizer significantly increased maize yield above control. The effect of either intercropping or rotation cropping system on crop yield and soil physical and chemical parameters will be determined from data of the second year.

Sinorhizobium americanum symbiovar *mediterranense* is a predominant symbiont that nodulates and fixes nitrogen with common bean in Tunisia

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A total of 40 symbiotic bacterial strains isolated from root nodules of common bean grown in a soil located in the north of Tunisia were characterized by PCR-RFLP of the 16S rRNA genes. Six different ribotypes were revealed. Nine representative isolates were submitted to phylogenetic analyses of rrs, recA, atpD, dnaK, nifH and nodA genes. The strains 23C40 and 23C95 representing the most abundant ribotype were closely related to *Sinorhizobium americanum* CFNEI 156T. *S. americanum* was isolated from *Acacia* spp. in Mexico, but this is the first time that this species is reported among natural populations of rhizobia nodulating common bean. These isolates nodulated and fixed nitrogen with this crop and harbored the symbiotic genes of the symbiovar *mediterranense*. The strains 23C2 and 23C55 were close to *Rhizobium gallicum* R602spT but formed a well separated clade and may probably constitute a new species. The sequence similarities with *R. gallicum* type strain were 98.7% (rrs), 96.6% (recA), 95.8% (atpD) and 93.4% (dnaK). The remaining isolates were respectively affiliated to *R. gallicum*, *E. meliloti*, *Rhizobium giardinii* and *Rhizobium radiobacter*. However, some of them failed to re-nodulate their original host but promoted root growth.

Physiological characteristics of rhizobia isolated from *Retama raetam* and *Lupinus various* indigenous to the Libyan desert

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Lupinus various is an indigenous legume growing in stressful arid conditions and plays an important ecological role in stabilizing soils and increase their fertility. The rhizobia of these legumes are as most, rhizobia inhabiting Libyan soil are not well explored and characterized. The aim of this study was to test in agar medium and select native rhizobial isolates that are

efficient of adaption to adverse soil conditions prevailing in the region. Twenty rhizobial isolates obtained from root-nodules of both legumes (*Lupinus various* and *Retma raetam*) were studied for their ability to tolerate local environmental and chemical stresses. Six fast- and one slow growing reference strains were included for comparison. Numerical analysis showed that the reference strains separated from test isolates. The majority of isolates displayed a high tolerance to extreme temperatures, some even grew at 48^0C and grew at alkaline and acid pH. Regarding tolerance to salinity on agar medium, the majority of the isolates grew at 6% NaCl, but some isolates from *Lupinus various* were more resistant, grew even at 8 % NaCl. Most isolates were resistant to heavy metals, but were sensitive to most antibiotics tested.

Response of common legumes in Zimbabwe to application of different fertilizer amendments

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Appropriate application of nutrients is important for smallholder farmers for the efficient use of nutrients in legume crops to maximize biological nitrogen fixation and increasing yield in degraded soils in southern Africa. A number of fertilization options were tested in Zimbabwe for soybean, cowpea and groundnut production under smallholder conditions in Zimbabwe. Compound L (NPKS), Single super phosphate (P, Ca, S), and dolomitic lime (Ca, Mg) were used solely and in combinations to determine the best nutrient requirements for the different legumes. Soybean yield was higher with the P-based fertilizers in poor sandy soil although yields were generally lower than 100 kg ha^{-1}. Soybean grain yield ranged from 25-90 kg ha^{-1} in un-inoculated plots compared to 160 kg ha^{-1} to 600 kg ha^{-1} in inoculated plots. Cowpea also responded well to SSP and Compound L application with highest yields attained in the combination of SSP and dolomitic lime (240 kg ha^{-1}) compared to 140 kg ha^{-1} in the zero control. However in a fertile soil, cowpea residue yield responded positively to nutrient addition (5000 kg ha^{-1} in the zero control vs 7000 kg ha^{-1} in the SSP + dolomite) at the expense of grain yield which had the highest yield of about 1000 kg ha^{-1} in the zero control compared to the lowest of about 500 kg ha^{-1} in the compound L + dolomitic lime, indicating possible luxury consumption. In soybean, yield was higher in inoculated treatments relative to the un-inoculated control, indicating low indigenous rhizobium numbers in the soil. Despite the strong response to fertilizer and inoculants in soybean, yields remained very low in all treatments (<700 ha^{-1}) in the granitic sandy soil. This suggests the need to combine both organic and inorganic manures for legume production in the highly leached granite derived soils in Zimbabwe.

Enhancing the responsiveness of smallholder communities to persistent problems of food insecurity and pending challenges of climate variability

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Increasing farm level productivity on a sustainable basis has remained a major challenge in many African countries. Millions of the predominantly smallholder farming households, particularly women- and child-headed families, are perennially food insecure and dependent of donor aid for their livelihoods. The pending negative impacts of climate change and variability have further heightened vulnerability of these food insecure households and social groups. Integrated soil fertility management technology options were evaluated with different categories of farmers in six smallholder farming communities in eastern Zimbabwe. The farmers differed in their resource endowments and access to agronomic and climate information. Mobilization of farmers into learning alliances in the context of participatory action research approaches enhanced participation of resource constrained households and other farmer groups in the testing of different ISFM options. A new concept of field-based Learning Centres was employed, and helped in the identification and testing of 'best-fit' soil fertility management options and agronomic practices that matched farmers' socio-ecological circumstances. The resultant dialogue with extension agencies, private agro-service providers, regional policy makers and farmers led to joint evaluation of legume-cereal rotational systems under different fertilization option. Combinations of mineral NPKS fertilizers and locally available organic nutrient sources that included livestock manure, woodland litter and crop residues increased mean maize yields from <0.8 t ha^{-1} to 7.6 t ha^{-1}. In response to emerging conditions of increasing rainfall variability, 80% of farmers prioritized drought tolerant and medium maturing maize cultivars that matured in <140 days. Out of three legume crops, namely, cowpea (*Vigna unguiculata*), soyabean (*Glycine max*) and groundnut (*Arachis hypogaea*), cowpea was most preferred by resource-constrained farmers. Cowpea was prioritized for its drought tolerance, early maturity, ability to offer multiple harvests for home consumption, and availability of its ready market. We concluded the ISFM technologies and field-based Learning Centre approaches provide the much needed entry points for intensification of legume-cereal cropping systems in Africa in the wake of increased climate variability.

Influence of repeated application of different quality organic amendments on soil fertility parameters and maize yield response on a sandy loam in Zimbabwe

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A long-term study was conducted to investigate the effects of organic resource quality and quantity on maize productivity, soil organic carbon (SOC), soil pH, available phosphorus (P) and exchangeable bases Ca and Mg on a sandy clay loam soil. Five different quality organic amendments (OAs) namely cattle manure, *Calliandra calothyrsus* (2.9% N), *Crotalaria juncea* (3.1% N), maize (*Zea mays* L.) stover (0.9% N), and sawdust (0.3% N) were applied annually on a sandy clay loam soil at

Domboshawa, located 30 km north of Harare, for eight years (seasons). The organic amendments were applied at high (4 t C ha^{-1}) and low (1.2 t C ha^{-1}) carbon rates with a basal fertilizer PKS also being applied to all plots at a rate of 26 kg P ha^{-1}. Maize productivity declined with time across all treatments from 5.2-8.0tha^{-1} in 2002/3 season to 0.36 – 6.4tha^{-1} in 2010/11 season. In a short-term (two year) study maize productivity followed the order: *Crotalaria juncea* >*Calliandra calothyrsus* > cattle manure = control > maize stover > sawdust suggesting that maize productivity was a function of organic resource quality but this trend changed after six seasons to follow the order: cattle manure > *C. juncea* > *C. calothyrsus* > maize stover > control > sawdust. In the long-term the measured soil parameters were, however, correlated to the trends in maize productivity. Significantly higher levels of SOC (0.82 and 0.83%), pH (5.0 and 4.5), available P (10 and 9.05 mg kg^{-1}), Ca (10.13 and 9.9 mg kg^{-1}) and Mg (5.2 and 6.5 mg kg^{-1}) were recorded under cattle manure and crotalaria respectively. Although soil pH under maize stover (4.43) was also significantly higher than the control, it did not influence yields. The soil parameters under calliandra, maize stover and sawdust were not significantly different from the control and SOC <0.75%, pH<4.0, Ca<7mg kg^{-1}, Mg < 2.6 mg kg^{-1} were recorded. We therefore conclude that short and long-term determinants of maize productivity under maize mono-cropping are different. In the long-term maize productivity determined by SOC and other soil properties such as pH, available P, Ca and Mg which are influenced differently by OAs regardless of their quality.

Effect of N, P and inoculation on promiscuous and non-promiscuous soybean

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Soybean (*Glycine max* L Merrill) is relatively a new crop in Mozambique but the demand is high due to the growing poultry industry. However, yields are limited by lack of improved varieties, poor cultural practices, and low use of inoculants and fertilizers. Enhancing soybean yield in Mozambique will therefore require inoculation, P and N application. This study evaluated plant growth, nodulation and grain yield of two soybean genotypes in response to N, P and inoculant (I) application. A field experiment was conducted at Ruace, Mozambique in 2010 using a determinate and non-promiscuous variety, Storm and an indeterminate and promiscuous variety, TGx-1904-6F. Granular inoculant containing *Bradyrhizobiaum japonicum* strain USDA 61A101, 40 kg N ha^{-1} and 40 kg P ha^{-1} were applied at planting. The inoculant was drilled into opened furrows in each plot. A split-plot design was used with 4 replications. P was assigned as the main plot whereas a factorial combination of genotype, N and inoculation were sub-plots. Nodules were sampled at 50% flowering, and whole plots harvested at maturity to determine grain yield. Significant ($p<0.05$) interactions occurred for all parameters. Nodulation and grain yield were higher in Storm compared with TGx 1904-6F although the latter produced relatively high shoot biomass. P application increased nodule number, shoot biomass and grain yield whereas N, I and N+I treatments significantly improved nodule numbers, plant growth and grain yield. The results suggest that the application of N, I and P can increase grain yield of soybean genotypes in Mozambique.

Profitability of rotation systems under varied integrated soil fertility management regimes in the Central Highlands of Kenya

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Legumes play a significant role in soil fertility management through nitrogen fixation but their uptake remains low among smallholders as partially evidenced by the wide supply-demand gap of grain legumes. Little attention has been accorded to the economic and profitability aspects that drive uptake of legume production among smallholder farmers. Conventional smallholder legume production in Kenya is intercropped or in a rotation system with maize. This study aimed at addressing the existing information gap regarding profitability of soybean, climbing beans and maize rotation systems in the Central Highlands of Kenya. On-station and researcher-designed and farmer-managed trials were carried out from March 2010 to March 2012. The inputs evaluated included sole manure, manure plus fertilizer, tithonia plus fertilizer and sole fertilizer. Economic and yields data collected was used to calculate net benefits, benefits cost ratio, return to labour and break-even points for varied integrated soil fertility management technologies for growing soybean, climbing beans and maize. Results showed significant differences in yields among treatments as well as seasons due to variation in rainfall amounts and distribution. Soybean yields ranged from 0.3 t/ha in control treatments to 2.5 t ha in manure and fertilizer treatments. Profitability also varied significantly among the three crops under the varied inputs used. The most profitable was maize under manure and fertilizer followed by soybean under sole fertilizer. In seasons with adequate rainfall, soybean recorded significantly higher net benefits under sole manure than the climbing beans and maize. Benefit cost ratios also varied significantly among the crops under different inputs. Maize under manure and fertilizer recorded relatively higher benefit cost ratio than the other crops.

Effects of tillage and cropping systems on arbuscular mycorrhizal communities in Western Kenya

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Conservation agriculture (CA) using zero-tillage, crop residue management and crop rotation is proposed as a remedy to soil degradation associated with agricultural practices that deplete soil organic matter in sub-Saharan Africa. However little is known on how these three CA principles interlink to influence the arbuscular mycorrhizal fungal (AMF) community in Kenyan agro-ecosystems. This study was carried out during long rains season (2008) and short rains season (2008-2009) to assess the effect of early tillage practices, cropping systems, retention of crop residues and nitrogen (N) fertilization on the AMF community. The

trial consisted of two tillage systems (Conventional tillage, CT and No till, NT), two cropping systems (continuous maize and maize-soya beans rotation), two crop residue management practices (2 t ha^{-1} yr^{-1} retained and removed) and two N fertilization levels (0 and 60 kg N ha^{-1}) in a complete randomized block design with three replicates. Measurements included AMF diversity and activity as well as soil properties in order to explain their influence on AMF community. AMF diversity was assessed through species richness, Shannon (H) diversity index and spore abundance while AMF activity was measured through mycorrhizal inoculum potential (MIP), hyphal length and root colonization of the field crops. Eighteen AMF species from *Glomus*, *Acaulospora*, *Scutellospora*, *Entrophosphora* and *Paraglomus* were observed. Tillage practices and N fertilization altered AMF species composition. Tillage declined spore abundance of G. aggregatum, *S. verrucosa* and *Acaulospora sp*.1 while N fertilization declined abundance of *Glomus aggregatum*, *S. verrucosa* and *S. persica* in field soil. No till systems and crop residues also increased spore abundance by 49.9 % while nitrogen fertilization declined spore numbers and species richness by 29.3% and 5.5%. Tillage, cropping systems and crop residues had no effect of species richness and diversity. No differences in total hyphal length were obtained under the two tillage systems, two cropping systems, two crop residues and their interactions. Slightly higher length was observed in N fertilized plots compared to unfertilized plots. AMF colonization of field crops was high in NT systems than CT systems (31.4 vs. 25.3%). The MIP was also improved by N fertilization, and was declined by retention of crop residues. N fertilization when in combination with crop residues under NT systems also declined MIP. It is concluded that a less disruptive effect of NT and crop residues have positive influences on AMF community and symbiosis in Western, Kenya.

Organic inputs and mineral fertilizer effects on soil chemical properties, soil water content and maize productivity in Mbeere District, Kenya

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Farmers in Central Highlands of Kenya experience declining agricultural productivity majorly due to soil desiccation and soil fertility depletion. Low soil water availability is caused by low and unreliable rainfall, poor water harvesting techniques and unsuitable farming practices. Therefore, in order to increase crop productivity, and reduce production risks, better use of available rainfall and improved nutrient use efficiency is required. One way of reversing the trend of declining land productivity in smallholder farms in Kenya, is believed to be the combined application of organic and mineral sources of nutrients. In order to investigate this, field trials were established in a dry land environment in Central Kenya, at Machang'a. The objective of the research was to assess the effect of organic inputs on soil nutrients, soil water availability and maize (Zea mays) productivity in semi arid region of the Central Highlands of Kenya. The study was carried out in Mbeere District, Kenya, representing a low potential area in terms of agricultural productivity due to low and erratic rainfall. The trial followed a randomised complete block design with three replications. The treatments consisted of four organic sources (*Tithonia diversifolia*, *Lantana camara*, *Mucuna pruriens*, and goat manure) combined with mineral nitrogen fertilizer, sole fertilizer and a control. Sole use of manure, tithonia and calliandra generally recorded the highest maize grain yield. Generally the maize grain yields were lower with the sole fertilizer treatments compared to the organics across the seasons and this can be attributed to poorly distributed rainfall. The sole organics had higher yields during the short rain seasons, while the combinations recorded higher yields during the long rain seasons. Manure was superior in terms of improving soil chemical properties such as soil pH, magnesium, potassium, calcium and nitrogen across the sites. Soil pH declined in most of the treatments, more so with the combinations of organics and mineral fertilizers compared to the sole application of organics such as lantana, mucuna and manure. Soil organic carbon declined in most treatments. The interaction of manure treatment with soil moisture especially during dry spells highlighted the synergetic benefits of ISFM not only in addressing soil fertility and organic carbon depletion but also as a means of addressing low soil water availability in smallholder systems.

Yield responses and profitability of soybean and maize production under different soil amendment options in southwestern Uganda

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As part of the strategy to achieve a Green Revolution in Africa, there is need for improved soil fertility management through appropriate soil management practices that are economically viable. However, farmers and extension workers are exposed to many soil management practices and yet it is not clear which option(s) give optimum agronomic and economic benefits. Thus, a study was conducted on-farm to establish the yield responses and profitability of soybean and maize production under different soil amendment options in Isingiro district, southwestern Uganda. The trials were run for two seasons i.e., between September 2010 and February 2011, and between March and July 2011 using improved soybean MAK 1 and maize Longe 5 varieties. For both crops, the study was established as a RBD with five treatments replicated 8 times under farmers' fields and in each case, experimental plots measured 10x10 m. Soil samples were taken prior to planting. For soybean, the treatments used per ha were: control with no external soil amendments; 5.0T of manure; 2.5T of manure + 12.5 kg P_2O_5; 12.5 kg P_2O_5; and 25 kg P_2O_5. The treatments/ha for maize were: control with no external soil amendments; 5.0T of manure at planting; 2.5T of manure + 12.5 kg P_2O_5 at planting + 39.5 kg N applied three weeks after planting; 12.5 kg P_2O_5 at planting + 39.5 kg N three weeks after planting; and 25 kg P_2O_5 at planting + 79 kg Nthree weeks after planting. At physiological maturity fresh grains were sampled per plot from a randomly selected area of 3x3 m. Samples were weighed and oven dried at 105^0C for 24 hours prior to taking the dry weights. Results indicated that application of 2.5 t/ha of manure + 12.5 kg P_2O_5 to soybean, increases ($P < 0.01$) the grain yields. Furthermore, application of 25 kg P_2O_5 on soybean; and 25 kg P_2O_5 at planting + 79 kg N/ha on maize, significantly ($P < 0.01$)

give the highest yields for the respective crops. In both seasons, soybean profitability was highest with 25 kg P_2O_5 application. In contrast, net losses were registered from the soybean control plots. For maize, application of 25 kg P_2O_5 + 79 kg N registered the highest economic returns during the September season. Thus, profitability from soybean and maize production can be optimized with application of 25 kg P_2O_5, and 25 kg P_2O_5 + 79 kg N, respectively, while if fertilizers are not applied, net loss is registered for either crop.

Calibration and validation of AquaCrop model for maize in sub-humid and semi-arid regions of the Central Highlands of Kenya

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Farmers in the Central Highlands of Kenya have been experiencing declining crop yields due to low soil water availability caused by low and unreliable rainfall and poor water harvesting techniques. To increase crop yields, and reduce production risks, research on better use of available rainfall and the interactions between effects of climate, soil and field management on crop production is required. Simulation models, driven by daily climatic data, can be used to predict the impact of long-term climate variability on the probability of success of a range of crop, water and soil management strategies thus providing an opportunity of 'accelerated learning' compared with the traditional multi-location, multi-seasonal and multi-factorial field trials. We calibrated the crop water productivity model AquaCrop for maize and validated its performance over 3 growing season with contrasting rainfall patterns at a sub-humid and a semi-arid site in Central Kenya. The results showed high goodness of fit between observed and the simulated canopy cover with a model efficiency (E) of 0.82 in a sub-humid site and 0.81 in a semi-arid site. The grain and biomass yield simulation was better for the sub-humid site (E = 0.96 for short rains season and 0.88 for long rains season) than for the semi-arid site, though the fit was still acceptable for the latter. Soil water contents showed high correlations between the measured and the simulated values in 3 depth intervals (0-15, 15-25, 25-35 cm). AquaCrop's high reliability for the simulations of grain and biomass yield implies that, when properly calibrated, it can be used in developing strategies for improvement of field management decisions by small scale farmers in reducing crop production risks through ex-ante analyses of rainwater management and field operations options prior to implementation of the best bets.

Effect of soil input application on yields of soybeans and climbing beans in a maize-legume rotation in Central Kenya

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Climbing bean and soybean have potential to contribute to increased food production, incomes and improved soil fertility. This work reports results of soil input application on yields of climbing beans and soybeans in a maize-legume rotation in 4 districts of varying agro-ecological and socio-economic conditions in the Central Highlands of Kenya. The work was carried out for four seasons from March 2010 to March 2011. The inputs evaluated were sole manure, manure plus fertilizer, tithonia plus fertilizer and sole fertilizer. There was an increase in yields in all input treatments beyond the control treatment. However, manure, manure plus fertilizer and tithonia plus fertilizer gave consistently the highest yields in all the four seasons. Soybean yields in these treatments ranged from 1.3 to 2.2 t /ha, while maize ranged from 4 to 6.6 t/ha. The treatments increased yields by more than 130% over the control in most treatments. Similar trends were observed with regard to biomass yield for climbing beans, soybean and maize. In addition, yields varied across the seasons and highly depended on rainfall distribution within the seasons. In seasons of good rainfall, yields were almost double those obtained during the seasons with poor rainfall.

Combined inoculation of commercial microbial and chemical products on survival and growth of tissue cultured banana in Kenya

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The efficacy of combined commercial products in enhancing survival and subsequent growth of tissue cultured banana under different soil conditions was investigated in the greenhouse. Tissue cultured banana cv. Gros Mitchel was inoculated with products containing *Bacillus* sp., AMF, *T. harzianum*, Myconate and their dual combinations. At the hardening phase, four soil media; Vertisol, Humic Nitisol, Rhodic Ferralsol and conventional nursery medium were used. Initial inoculation of plants with products was done at the hardening phase and subsequently at the potting phase. Survival of inoculated plantlets was recorded at the end of the acclimatization phase, 8 weeks after deflasking. Destructive harvesting was done at end of nursery phase (20 weeks after deflasking). Root and shoot biomass was assessed and shoot analyzed for nutrient uptake. Plant growth and mycorrhizal colonization was assessed at the end of nursery phase. Characterization of soils and roots from field banana trials inoculated with products (*Bacillus* sp., AMF and *T. harzianum*) was also carried out in three agroecological zones in Kenya i.e. Central, Coast and Western to establish the occurrence of AMF, *Fusarium* and *Trichoderma* communities and the chemical and physical properties of soil. AMF spores were extracted from the soil, MPN experiment was done and root colonization assessed to establish the level of AMF colonization. Effect of the products on the measured parameters depended on soil type with Rhodic Ferralsol and Vertisol being more receptive to the treatments. Combined treatments showed the highest significant increases but there were cases where single products performed better than the combined ones. The combination of *Bacillus* sp. with AMF, *T.*

harzianum or Myconate gave the most significant effect on plant growth parameters and plant biomass accumulation. The products used in the greenhouse did not affect mycorrhizal colonization while those used in the field had varying effects on mycorrhizal colonization. Trichoderma was not present in the soil but many colonies of *Pencillium* were observed on the *Trichoderma* selective media. Three species of *Fusarium* (*F. proliferatum*, *F. oxysporum* and *F. incarnatum*) and other fungi were observed in varying populations. Results demonstrate that tissue cultured bananas can benefit from application of arbuscular mycorrhizal fungi, *Trichoderma*, *Bacillus* and a chemical stimulant to improve survival and growth during the nursery phase as well as enhance plant performance under field conditions. The effect of inoculation however depends on soil type.

Groundnut production as influenced by row planting methods and irrigation frequency in a Sudanese savanna

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Field management techniques greatly influence the various vegetative and reproductive processes of the groundnut crop. Strategies such as method and time of planting, irrigation scheduling and methods that aim at improving the yield of crops are thus highly desirous since it is the most important aspect of crop production. An experiment to study the growth and yield of groundnut in response to planting methods and irrigation interval was conducted in 2010 dry season. The experiment was laid out in a randomized complete block design with two planting methods (single row and double row stand) three irrigation frequencies (7, 14 and 21-day irrigation interval). The results show that Samnut 23 performed better than Samnut 21 while irrigating at 21 days interval resulted to higher groundnut yield.

Variation of nutrient content in soils of South Kivu, DR Congo

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Quantification of soil nutrients of smallholder's farms is important to understand and design sustainable soil-crop management decisions. To standardize procedures in establishing a regional framework for degradation surveillance and diagnoses of soil health constraints, Africa Soil Information Service (AfSIS) approach was used. Two sentinel sites, Burhale (2.700°S, 28.632°E) and Luhihi (2.305°S, 28.858°E) were concerned by this study and each one is extended over 100 km^2 (10 km x 10 km). Based on the dorsale du Kivu soil map, the two sentinel sites are laid on Ferralsols. The aim of this study was to assess the variability of soil nutrient content within two AfSIS sentinel sites in south Kivu. This information will be used in combination with diagnostic trials to design integrated soil fertility management technologies for this area. Each sentinel is divided into 16 equal clusters and each cluster is divided into 10 plots. From these plots 534 composite soil samples were taken at two different depths; top soil (0-20 cm) and sub soil (20-40 cm) in cultivated and uncultivated land. All samples were analyzed using NIR spectroscopy, while 10% of samples have been analyzed by traditional chemical methods. Soil chemical properties include pH and soil salinity and sodicity, available phosphorus (P) and potassium (K), exchangeable calcium (Ca) and magnesium (Mg), micronutrients and organic matter. Micronutrients include available Boron (B), iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu). Sulfur (S) and aluminum (Al) are considered separately. Organic matter status includes organic carbon, inorganic carbon, and total nitrogen. Results show that the whole area is acid. The topsoil pH average was 4.6 ± 0,34 in agricultural land in both sites. Cultivated lands are more depleted in nutrients and seem to be more degraded than uncultivated land. Luhihi sentinel site is richer in most nutrients than Burhale, e.g. nitrogen, phosphorus and potassium. Phosphorus deficiency is acute for Burhale (2.43 ± 3.5 mg P kg^{-1}), but less for Luhihi (5.36 ± 4.6 mg P kg^{-1}). In both locations, low levels of exchangeable Ca (<4 cmolc kg^{-1})and Mg (<2 cmolc kg^{-1})were found. Soil organic matter levels were also higher in cultivated plots in Luhihi (3.9 ± 0.4% C) than in Burhale (3.0 ± 0.4% C). All together this shows that soil fertility has declined more in the Burhale than Luhihi site. This is probably due to, not only farming systems but also, soil forming parent material which is different in the two sites. Finally high soil nutrients variations were found between different clusters in one sentinel site. Nitrogen average in Burhale (mean 0.24±0.10%) was 0.30± 0.14% in cluster 5 while it was 0.10±0.05% in cluster 6.

African traditional vegetables as an alternative source of nitrogen

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African traditional vegetables have for a long time been used as an alternative source of treatment for various ailments. Little efforts were made to try and find out if there could be another significant importance they could be having. This led to a study initiated at the Sustainable Development Initiatives Centre in the United States International University to try and find out if the African Vegetables have any value apart from the medicinal ones. At the end of the study, results showed that African Vegetables have the ability to fix nitrogen i.e. can convert the free atmospheric nitrogen into nitrates that can be used as fertilizer for the vegetables themselves as well as the crops closer to the vegetables. Five different types of traditional vegetables namely; Amaranthus spp, Spider Plant, Crotolaria, Jews mallow, African nightshade were selected to carry out the study at the Sustainable Development Initiatives Centre garden. All the five different vegetables were planted on the same day and time but with equal amount of different fertilizers and some with no fertilizer at all and subjected to same conditions.The garden was subdivided into 15 sections; five each. The first 5 were planted using organic fertilizer, the second used commercial fertilizer

(DAP) while the last 5 were planted without any fertilizer. All of them were subjected to same conditions and closely monitored for any changes that could arise. The changes that were to be observed included leaf color, number of leaves, root length, stem length, number of nodules and pods.Harvesting commenced after 2 weeks and was kept at a 2 week-constant, where-by any observable changes were recorded. It was noted that Crotolaria, developed nodules. But their growth also showed some variations; those that were planted without any fertilizer seemed to thrive well as compared to the rest. This phenomenon could be attributed to the fact that the vegetables - Crotolaria, - having nodules, have the capability to convert the free atmospheric nitrogen into nitrates that in turn is used up as nutrients by the plants.With this knowledge, it is advisable and encouraged that traditional vegetables be cultivated in soils that are unfertile as they have the capability to make their own nitrates. It is advisable that these vegetables be intercropped with other crops that are not nitrogen fixing, for example, maize and sukuma wiki.In this context, therefore, it is recommended that traditional African vegetables be embraced as an alternative source of nitrogen in the soil. And so, in modern farming and in order to achieve increased harvest, let us encourage the cultivation` of traditional vegetables.

Effects of mycorrhizal infection on bean and tomato cropping systems in Kivu Province, DR Congo

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Previous experiments showed that 76.7% of crops grown in eastern and central Africa rely on animal pollinators to set fruit/seeds. Others studies highlighted that moisture, some soil nutrients (magnesium, boron, calcium, nitrogen, and phosphorus) and pest pressure are critical in the phenology, blooming, fruit set and yield and yield components on these pollinator-dependent crops. A study was conducted to investigate the impact of mycorrhizal infection on soil phosphorus availability, soil nutrients and water availability on pests pressures, pollinator visitation rates and on fruit set, yields and yield parameters of different genotypes of beans (*Phaseolus vulgarus* L.) and tomato (*Lycopersicon esculentum* L) grown in different soils types and in eastern DR Congo. The results indicated that different bee species visited crop flowers but some bee species in the Halictidae, Megachilidae and Apidae families were the most dominant pollinators (91% of total pollinators). The bees spent significantly ($P>0.05$) equal time on flowering plants of all treatments (un-sprayed crop, un-water stressed plants, etc). There were significant ($P<0.05$) differences among study sites for yield of the two crops. The distance at which a field experiment was located to pollinator- refugia was significant. Variety/genotype effect was not significant ($P<0.05$) but soil type had a significant ($P<0.01$) effect on yield and yields components. Mycorrhizal infection and high soil P conditions significantly ($P<0.05$) increased production of floral resources (pollen, nectar) of high quality, high attractiveness of different bee species, fruit set and yield of beans and tomato. There was no significant difference in attraction (visitation intensities) of different bee species to flowers from plants under different water, fertilization and pest treatment. There were synergestic effects of the different treatments. However, there was a significant interacting effect on fruit set and yield for beans. The beneficial effects of soil nutrients and moisture contents occurred when fields were established in the vicinity of semi-natural habitats (reservoirs of different pollinator species) .The interaction pest management and soil nutrients was not significant ($P<0.05$). The interaction of soil nutrients, moisture availability and pesticides applications treatments were significant ($P<0.05$) for pollinator visitation rates and for fruit set and yield of beans (not tomato). Different bee species performed well their fertilization activities of the crops when most of the parameters (treatments) were optimal at the field plot. Fields results were of similar trends to greenhouse results. Thus, mycorrhizal infection and high soil P conditions (particularly from budding to blooming periods of the crops) coupled to pest control, nutrients supplements increased pollen quality (as well as pollen quantity) and attraction of efficient pollinator species, thereby enhancing crop yield through the pollination services delivery to crop flowers by different bee species.

Quantification of within-farm soil fertility variation in East African smallholder farms

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Agricultural growth Sub Saharan Africa (SSA) is hampered by a growing soil productivity crisis which is attributed to greater removal of nutrients in crop harvests than those returned each year among other factors. Whereas crop intensification has been achieved through widespread use of fertilizers elsewhere, fertilizer consumption in SSA still lags behind due to factors such as high commodity prices, poor infrastructure, reliance on traditional crop varieties and increasingly unpredictable weather patterns. For many smallholder farmers, application of organic resources (if available) is the only reliable way to replenish lost nutrients. Due to their bulkiness and low nutrient concentration, farmers preferentially apply organic resources to fields closest to the homestead, in the process,paving way creation of within-farm soil fertility gradients with prolonged application. Within-farm soil fertility variation is widely visible in the densely populated East African humid highlands, owing to differential land use reacting to strongly market oriented smallholder dairy, tea, coffee and horticulture systems; semi-commercial cereal-legume systems and starch-based subsistence systems. In a project that hypothesized that within-farm soil fertility gradients were large enough to be taken into account when planning the allocation of scarce nutrient inputs at the farm level, 250 farms were characterized in Kenya and Uganda to determine the biophysical and socio-economic drivers of heterogeneity using a Y frame. The study confirmed that within-farm soil fertility variation existed, most of which could be explained by positioning of fields on the landscape, distance from the homestead and land-use (extractable P =95%; soil org C =98%). Farmer soil fertility assessment performed on a field by field basis, closely agreed with measured values of extractable P and soil organic C (74 %, low; 72% medium and 67% high), thereby underscoring the importance of applying local soil quality indicators in the formulation of ISFM recommendations.

Potential of grain legume fallows to improve household food security and financial returns: Lessons from a pigeonpea trial in western Kenya

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The understanding of agronomic and financial implications of integrating pigeonpea (Cajanus cajan) fallows into smallholder cropping systems in sub-Saharan Africa is limited. A pigeonpea fallow-maize crop rotation trial was carried out over a period of 4 seasons in western Kenya. The trial compared six high altitude long duration pigeonpea varieties i.e. ICEAP 00020, ICEAP 00040, ICEAP 00048, ICEAP 00053, ICP 9145 and ICP 13076 and a medium duration variety i.e. ICP 13211 for productivity, post fallow maize crop yield and financial returns. Continuous maize cropping acted as a control. Depending on the variety, pigeonpea grain yield ranged between 1.3 and 1.9 t ha^{-1}. Post fallow maize grain yield from each of pigeonpea variety plot was approximately 3 fold higher than yield from continuous maize plots. The medium duration pigeonpea plots yielded significantly higher maize grain than ICEAP 00053 and ICEAP 00040 pigeonpea variety plots. Relative to the control, incremental returns to land were highest for medium duration pigeonpea fallow plots (619 USD ha^{-1}) and lowest for ICEAP 00040 fallow plots (305 USD ha^{-1}). We estimated that by selecting an appropriate pigeonpea accession for a fallow-maize rotation system, a household could produce sufficient food for consumption and remain with a surplus of approximately 2.8 tons for sale. For widespread adoption of pigeonpea based technologies in western Kenya, there is a need for policy improvement on issues related to improved seed production systems, cost of fertilizers and market for the end products.

Bio-prospecting elite soybean and bean rhizobia in Kenya

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Africa is home to genetically diverse legume root nodulating bacteria that present opportunities for discovery of highly effective strains for use in formulation of inoculants. Previously, few studies were performed in Kenya to comprehensively assess this diversity and evaluate its nitrogen fixing potential with economically important legumes such as soybean and bean. In this study, root nodulating bacteria were isolated from cultivated and wild legumes growing in various ecosystems ranging from coastal sand dunes to high elevation montane regions in western Kenya. The isolates were characterised morphologically on yeast mannitol agar plates containing congo red and bromothymol blue while gram reactions were done using the Ryu nonstaining potassium hydroxide technique. Isolates were authenticated with bean and soybean in Leonard jars or three litre pots containing sterile vermiculite. Performance of authenticated strains on bean and soybean was then evaluated in a sterile vermiculite system. Data collected and analysed included shoot dry weight and nodule numbers. A total of 208 strains were collected from 20 legume genera. Most hosts (83%) belonged to the tribe Phaseoleae and as many as 26% were isolated from bean and soybean. Isolates were described as slow (52%), intermediate (1%) and fast (47%) growing. The strains had marked differences in their abilities to infect and fix N with soybean and bean as the shoot dry weight means of the treatments were significantly different ($P= 0.05$). Isolates were categorised as inefficient, partly efficient, efficient or highly efficient in relation to the performance of commercial reference strains. These preliminary results confirm the presence of diverse indigenous rhizobia in Kenyan soils that are effective on bean and soybean. Promising strains are to undergo more robust performance evaluations and genetic fingerprinting for identification.

Effect of cattle manure, mineral fertilizer and rhizobium inoculation on climbing bean production and soil properties changes in Burera District, Rwanda

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Known as “meat for the poor”, beans constitute a predominant source of proteins in Rwandese diet since they supply 65% of national dietary protein compared to 4% from animal sources. The on-farm productivity of about 0.8–1.0 t/ ha is quite low compared to 5 t/ha that is achieved under optimal management conditions. Diseases, lack of improved seeds, small size plots, low use of organic and inorganic fertilizers, and lack of affordable staking innovations are among the main reasons for the low productivity experienced by farmers. The aim of this study was therefore to evaluate the effect of cattle manure, mineral fertilizer and rhizobial inoculation on production of climbing beans and subsequently the soil properties in Burera District. The experimental design was a split-plot in completely randomized design (CRD) with two main plots (with and without rhizobial inoculant); four sub-plots (Cattle Manure, DAP, Cattle Manure + DAP, untreated control) with quantities applied at single level for each treatment, i.e. 20 t/ha for Cattle Manure, 50 kg/ha for DAP, 100 g in 15 kg of beans for inoculant. The experiment involved 8 treatments which were replicated three times to give 24 plots. At the start of the experiment, the soil was sandy loam, slightly acidic (pH=6), with weak stability of aggregates (10.25%), had a high percent of organic matter (8%) as well as a high cation exchange capacity (> 50 meq/100 gr), 8.29 ppm of nitrate nitrogen, 10.63 ppm of ammonium nitrogen and 18 ppm of available phosphorus. The soil properties did not change during experimentation period. The findings for the yield showed statistically significant difference ($P< 0.0001$) between inoculated plots (mean yield=3900 kg/ha) and non-inoculated ones (mean yield=2946 kg/ha). Statistically significant differences were also found between treatments ($P<0.0001$) with a mean yield of 4782 kg/ha in plots treated with Inoculant + DAP + Cattle Manure against 2640 kg/ha in untreated control plots. The number of nodules was significantly different ($P< 0.0001$) between inoculated (60 nodules) and non-inoculated (15 nodules) plots. The highest number of nodules (95) was found in plots treated with Inoculant + DAP + Cattle Manure; the lowest (14) in the untreated control plots ($P<0.0001$). Regression analysis between yield and nodule number showed a coefficient of determination

R^2 =0.8 and a p value < 0.0001, which confirmed the dependence of the yield on nodules number. In terms of cost-benefit analysis, a farmer can gain a benefit of about 1,200 USD in season one and 2,200 USD per season in the following ten seasons on one hectare. According to these results, a combination of mineral fertilizer, rhizobial inoculant and cattle manure would be better for increased yields as well as soil health in general.

Knowledge, attitude and practices of striga control in maize farms of Western Kenya

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The parasitic weed *Striga hermonthica* has become one of the most significant constraints to cereal production in western Kenya. A study was carried out to evaluate farmers' knowledge, attitude and practices in the control of *S. hermonthica*. A semi-structured questionnaire was administered to 120 farmers in January 2012 in three districts (Busia, Kisumu West and Teso South). It was discovered that all farmers were aware of striga weed and 99% revealed to have *Striga hermonthica* in their farms. The spreading agents were listed to be; wind (26%), animals (25%), farm implements (10%), water runoff (6.7%) and combination of them all (32.3%). Besides village meetings (39.2%), farmers also get informed through neighbours (2.5%), who are good implementers of technologies/practices, through attending free workshops and training (5.0%), field schools (3.7%), media (7.5%), from extension staff belonging to both international and local NGOs, Ministry of Agriculture and the Kenya Agricultural Research Institute (10.8%). Long-term viability of the striga seed (12.5%), difficult to control sharing of tools (10.8%), expensive technologies (13.3%), lack of adequate information (18.3%), labour intensive (15.0%), large farms for desmodium technology (1.7%) and time consuming (12.5%) are some of the strong attitudes farmers have towards striga control. Striga reduction technologies that were employed by the farmers were; striga resistant seeds (3.3%), intercropping maize with legumes followed with cassava (1.7%), push and pull (2.5%) and traditional methods i.e. uprooting, removing from the farm and burning (25%). Despite farmers being knowledgeable on the devastating effects of striga, their control strategies vis-à-vis the many technologies that have been developed to control the weed are limited. Concerted effort involving the researchers, extension agents and private sector are required for wide scale dissemination and adoption of the already developed striga control technologies.

Which households are most likely to take up ISFM technology and why? Case of Sidindi, Western Kenya

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Smallholder agriculture in western Kenya stands at crossroads leading to perpetual food insecurity among the farming communities. Excellent progress is being made in crop improvement, seed systems and crop pest/diseases no longer pose a major threat to crops. However, poor soil fertility and nutrient depletion continue to represent huge obstacles to the achievement of food security. This dilemma could be solved by the use of integrated soil fertility management (ISFM). ISFM is the application of soil fertility management practices, in combination with the right germplasm and knowledge to adapt to the local conditions which maximizes the utilization of fertilizer and organic resource use efficiency and crop productivity.This study estimates the percentage of adoption of ISFM practices by various households and evaluates the factors that determine their adoption. Agronomic and household social-economic data was collected from 311 farming households in the Siaya area of Western Kenya during the long rains season of 2011. The study used spatial and probit models to analysis the data. Results showed that access to agriculture information, particularly from farmer groups played a significant role in determining the intensity of ISFM ($p < 0.1$) by various households. Age of the household head, rented tenure and farmers' perception on soil erosion had a negative influence on the adoption intensity of ISFM technologies. Farmers' access to information and farming knowledge through farmer groups made them aware of ISFM technologies. Keeping the youth (19-25 yrs) interested in farming are likely factors that could be used to enhance adoption of ISFM technologies by households since the youth are more receptive to new technologies and are willing to improve their farm productivity as compared to elderly household heads.

Tillage, legume and soil management effects on sorghum yield in Eastern Uganda

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Grain sorghum [*Sorghum bicolor (L.) Moench*] is an important food crop in semi-arid areas of sub-Saharan Africa. Sorghum yield is limited by numerous constraints in Uganda, with soil water deficits, the stem borer complex and *Striga* spp., and N deficiency being the most important ones. Sorghum yield response to alternative soil fertility management strategies were evaluated under Reduced Tillage and Conventional Tillage (CT) systems and in rotation with a herbaceous legume i.e. mucuna as compared to a grain legume i.e. cowpea over five years in Jinja-Mbale Farmlands and Southern and Eastern Lake Kyoga Basin of eastern Uganda. There was a significant ($P < 5\%$) increase in sorghum grain yield above the control ($1.0 – 1.8$ t ha^{-1}) in response to application of kraal manure, combination of kraal manure and inorganic fertilizers compared to the control (0.5–1.4 t ha^{-1}) under the two tillage systems. The overall sorghum yield under mucuna–sorghum rotation was significantly different ($p<5\%$) as compared to a cowpea-sorghum rotation due to a higher biomass production and N input through mucuna residues. No significant difference in sorghum yield between the two tillage systems was observed. This implies that using herbicides instead of hand hoes and the subsequent reduction by one in the number of weeding was not was not manifested in terms of yield

increase. The results confirm that low soil fertility is a constraint to sorghum production in Uganda and the use of alternative strategies will result in increased crop yield hence food and income security.

Molecular tools for tracing arbuscular mycorrhizal fungi and plant growth-promoting rhizobacteria

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A "next-generation green revolution" towards a more sustainable, low-input but still highly productive agriculture is urgently needed. A key for this is "below-ground": The intricate interplay of plant roots with the soil microbiota is crucial for natural soil fertility and, thus, for any sound agro-ecosystem. To harness this below-ground potential and to apply it in agriculture, the ISCB-Biofertilizer network, a consortium of Indian and Swiss research groups, tries to develop a "biofertilizer" based on the two most important symbiotic soil microbes, namely the arbuscular mycorrhizal fungi (AMF) and the plant growth-promoting rhizobacteria (PGPR). Recently we have shown that combined application of AMF and PGPR improves the yield and quality of wheat in marginal farms of India. An important aspect for developing the formulation of AMF and PGPR to a successful "biofertilizer" is the ability to trace the microbial strains involved, ideally with the help of unique, DNA-based diagnostic tools. This does not only help to establish the survival of the applied microbes in field condition but also to validate its persistence over time.The molecular markers currently in use for AMF are based on the highly variable "ITS" region of rDNA, a genomic region used for monitoring purposes in many organisms. However, this region displays an unusually large variability within a given AMF strain. We have developed strain-specific DNA markers for *Glomus intraradices* (currently called as *Rhizophagus intraradices*), based on "microsatellite" sequences of the nuclear genome and on sequences of the large rDNA of the mitochondrial genome. These novel markers do not show intra-clonal variation, and therefore they have an immense potential to trace AMF strains in the field, both in basic and applied research.The basis of detecting bacterial species using DNA sequences is more straightforward due to their simple genome structure. Usually the 16S rDNA gene is used for identifying a bacterial species. However, tracing a specific PGPR strain using 16S rDNA tool in field samples could be difficult, especially since often there are indigenous strains that are genetically similar to the target strain. Nevertheless, highly polymorphic multilocus marker systems, such as microsatellites, will allow discerning the target strain from native strains. Developing such multilocus marker systems requires a large amount of sequence information from the target strain, which can be achieved by partial or complete genome sequencing. Within the ISCB-Biofertilizer network, we have recently sequenced the complete genome (GenBank accession numbers AHZM00000000 and AHZN00000000) of the two PGPR strains belonging to the group of fluorescent *Pseudomonas*. We used the genome sequence information and developed microsatellite markers for tracing our target PGPR strains in field samples. Our diagnostic tool for identification and quantification of individual AMF and PGPR strains will set a new standard for quality control and tracing of biofertilizer products, a standard not only of interest to the ISCB-Biofertilizer project but to the institutions and industries serving the farming communities world-wide.

Can commercial microbial inoculants and new foliar fertilizers increase groundnut yield under low fertility soils in the Sudanese Savanna?

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Groundnut production in Sudanese Savanna is threatened by the gradual depletion of soil macro/micro-nutrients due to high population pressure on arable soil and lack of efficient farming system management. In addition, small-scale farmers encounter difficulties in using inorganic fertilizers although their application has a destructive effect on soil resources. Therefore, biofertilizers are beneficial in agricultural practices for environmental safety and sustainability of soil productivity. The aims of this work were to evaluate the effect of commercial AMF and rhizobacteria inoculants on groundnut shoot phosphorus (P) concentration and grain yield and to investigate the interactive influence of microbial inoculants and foliar fertilizer with rhizobium inoculant on groundnut nodulation, shoot nitrogen (N) and P concentration, and grain yield. Field experiments were carried out during the cropping season in Shanono and surrounding villages in Kano State, Nigeria. In one experiment, the application of AMF commercial inoculant (Rhizatech) showed positive effect in shoot dry weight production (16%), shoot P concentration (2.5 g/kg), and pod initiation (120%). In the second experiment, the shoot dry weight production was increased by Rhizatech (104%), TSP-RACA6 (58%) and Agroleaf high P (54%) treatments. TSP application gave the highest nodulation (40.96%) and grain yield (72%). The combined application of RACA6-Rhizatech (25.07 g), RACA6-Agroleaf (23.43 g) and RACA6-Eco-T-Agrolyser (23.28 g) enhanced the grain yield more than the single application. The positive effect of microbial inoculants and foliar fertilizers in increasing groundnut production is promising but there is a need for further investigation and mass trial implementation for validation.

A situational analysis of opportunities and challenges of using ISFM information and knowledge in Kenya

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Integrated Soil Fertility Management (ISFM) research has been done in many parts of Kenya over the years. Researchers and development workers have come up with promising ISFM recommendations which have potential to improve agricultural productivity and food security in Kenya. The uptake of improved ISFM technologies can lead to sustainability in agricultural

productivity, but Kenyan agricultural food production remains low. ISFM findings are usually published in conference proceedings, journals, book chapters, thesis, annual reports and others kept in office shelves or soft copies either as raw or processed unpublished data, which is either accessible or inaccessible by other soil fertility end users. Lack of soil fertility knowledge and fertilizer use information is a major handicap to fertilizer use and uptake of soil fertility technologies by smallholder farmers who are the major custodians of the soil resource base. Disseminating ISFM knowledge and developing incentives for its adoption is a big challenge to national planners and rural development specialists. At the same time, there is general lack of awareness of the benefits which may be realized from the use of ISFM technologies and lack of consolidated ISFM information. However, it has been found that agro-dealers could be the most effective extension agents if equipped with ISFM information as they are in constant contact with smallholder farmers whenever they are purchasing farm inputs. Compilation and availing of comprehensive harmonized soil information will improve estimation of current and future land potential productivity enhances assessment of risks of land degradation. This analysis highlights successful ISFM research findings, soil information gaps and adoption constraints among the smallholder farmers in Kenya.

Response of *Acacia senegal* seedlings to inoculation with arbuscular mycorrhizal fungi, rhizobia and *Pseudomonas fluorescens*

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The effects of arbuscular mycorrhizal fungal inoculum (M) individually and in combination with rhizobia (R) and *Pseudomonas fluorescens* (P_f) were investigatedon the growth and nutrition of *Acacia senegal* seedlings. *A. senegal* is a multipurpose leguminous economically and ecologically important in sahelian areas. In glasshouse conditions, all the inoculums except *Pseudomonas fluorescens* enhanced significantly *A. senegal* plant growth after 6 months of culture in a non-sterile soil from Dahra (Senegal). However, no significant increase in shoot N content was recorded whereas the application of MR, MP_f and MRP_f improved significantly shoot P content, and that of MR and MP_f, shoot K content. The nodule number was significantly augmented by rhizobial inoculation, and the root colonization rate by MR, MP_f and MRP_f treatments. Soil spore density was increased by all inoculums except MP_f, and soil hyphal length by M, R and MRP_f treatments. The inoculation with *Pseudomonas* and MP_f stimulated significantly soil acid phosphatase activity, but no significant effect was observed on soil FDA activity. Thus, the dual inoculation with AMF and rhizobia can be beneficial to *A. senegal* growth under non-sterile soil, where nutrients particularly P and N are often deficient. These results demonstrated the importance to test out the proper selection and compatibility between those microorganisms for better improvement of *A. senegal* plant growth.

Relative effectiveness of agricultural lime and local lime materials in reducing soil acidity in Rwanda

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The aim of this study was to evaluate the quality of different local limes and their relative effectiveness in increasing soil pH in acidic soils of Burera District, Rwanda. The lime materials in this study were agricultural lime and three local lime materials; Karongi, Musanze and Rusizi. All lime materials were first analysed for Calcium Carbonate Equivalent (CCE), Effective Calcium Carbonate Equivalent (ECCE), Fineness factor, limes acidity and moisture content. After lime analysis, evaluation was conducted in a field trial. The field trial was a Randomized Complete Block design established in September 2011 at Rwerere research station of RAB (Rwanda Agriculture Board). The treatments comprised of the four lime materials applied at four levels: 0, 1.4, 2.8 and 4.3 t ha^{-1} of $CaCO_3$ equivalent. Lime application was done two weeks before planting. Soil pH, exchangeable Al and available phosphorus were analysed at 6, 12 and 16 weeks after lime application (WAP). Nitrogen and base saturation were analysed at 16 WAP. Relative Effectiveness of Limes (REL) in affecting soil pH and exchangeable Al evaluated after 16 weeks of limes application. The findings showed that agricultural lime and Rusizi had similar CCE of 86.36% and 85.46% respectively, but Karongi and Musanze had 68.48% and 66.2%, respectively. Agricultural lime and Musanze had finer particles than other local limes. The application of 2.8 t ha^{-1} of Musanze local lime and agricultural lime had similar effects in increasing soil pH and they increased soil pH_W by 0.65 and 0.64 units, respectively. Rusizi and Musanze applied at 4.2 t ha^{-1} had REL of 102.3 and 86.2%, respectively, but Karongi had 44.6% only. However, the application of 2.8 t ha^{-1} of Musanze local lime had 101.2% of REL, thus is more effective in reducing exchangeable Al than other local limes. Lime rate of 2.8 t ha^{-1} of agricultural lime, Musanze and Rusizi local limes increased available P by 1.72, 1.71 and 1.65 mg/kg, respectively. On the other hand, agricultural lime and Musanze local lime had similar effects in increasing Ca saturation in the soil. The application of 1.4 and 2.8 t ha^{-1} of agricultural lime and Musanze local lime increased total soil N by 0.12 to 0.24%. Therefore, this study recommends the use of 1.4 to 2.8 t ha^{-1} of either Musanze or Rusizi local limes depending on the targeted location to be limed.

Effects of soil and water conservation techniques on runoff, sediment yield and maize productivity

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To improve agricultural crop productivity and reduce erosion rates and its effects on the environment of the humid and sub-humid regions in the tropics of sub-Saharan Africa, it is necessary to reduce sediment and runoff losses while improving rainfall use efficiency. With these background an experiment was set to investigate the consequences of selected soil and water conservation techniques and tillage practices on runoff amounts, sediment yield and maize yields, the effects of minimum tillage (MT), conventional tillage (CT), Mbili intercropping (MI), mulching (MC) and tied ridging (TR) under semi-arid and sub-humid environments. Field trials were set in both humid and sub-humid sites in the Central Highlands of Kenya. Tied ridging was the most efficient technique in reducing runoff and sediment yield and at the same time boosting crop yields in the sub-humid region. It reduced sediment yields by 94% compared to the CT. During the drier season of short rains 2010, grain yield under TR was 7 times higher compared to CT. In the humid region, MT generated high rainfall but relatively low sediment yield compared to CT. In seasons of enough rainfall in the sub-humid site, intercropping suppressed maize yields by 42% compared to conventional tillage. The results on the magnitude of runoff and sediment under the different soil and farm management practices are crucial in selection and promotion of valid farm management practices and tillage alternatives that not only abate soil erosion but also boost agricultural productivity through enhanced water resource management in sub-humid regions.

The potential application of ISFM principles in improving rice production in lowland rainfed and irrigated ecologies of East Africa

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Rice production in east and southern Africa has increased as a result of the growing realization of the crucial role rice plays in household food and income security. However, in recent years rice productivity per unit area has stagnated due to abiotic and biotic factors. This paper reviews the application of Integrated Soil Fertility Management (ISFM) principles on lowland rainfed and irrigated rice in east and southern Africa. Farmyard manure, leguminous and cereal crop residues remain central to improving and maintaining soil fertility in rice systems. Mineral fertilizers are used sparingly as sole nutrient sources and in combinations with organic fertilizers however their current use is limited. Compared to sole mineral fertilizers, organic manures have resulted in higher rice yield gains due to lower nutrient losses. More synchrony and hence better yield gains have been attained as a result of combining organic and mineral fertilizers. Symbiotic biological nitrogen fixation (BNF) on both grain legumes and green manures has been successfully applied to improve rice yields. Only a few legumes have been identified to date for use under flooded lowland conditions prompting the need for more screening. While the application of *Azolla sp*. has shown a positive effect on rice, drought and the need for inocculum limits its widespread use. Low P contents in organic fertilizers limit their effectiveness as macro-nutrient sources. Where soils are P deficient, both microbe driven BNF and animal manure technologies are of little value. We conclude that combinations of ecology-specific mineral fertilizers, farmyard manure and short season legumes that tolerate low P soils, drought and flooding have the potential of improving rice yields. Further research on the application ecology specific ISFM technologies is required in view of land degradation and climate variability. There is need for further screening of fertilizer equivalency values of farmyard manure and crop residues and fortification of organic fertilizers to improve N and P availability in soils.

Application of DNDC model to maize cropping systems under organic and mineral fertilizers management practices in western Kenya

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Numerous studies conducted in western Kenya have quantified effects of organic and inorganic fertilizer additions on maize grain yields and potential contributions to soil organic carbon in maize based cropping systems. Despite the vast resources required to conduct field experimentation, biophysical heterogeneity inherent in the region's maize-based cropping systems often results to conflicting yield and SOC estimates that hinder comparisons of different fertilizer management practices in space and time. DNDC (i.e., DeNitrification - DeComposition) is a biogeochemical computer simulation model used to predict crop growth characteristics and carbon and nitrogen dynamics in terrestrial agro-ecosystems. The study explores the utility of modeling grain yield responses under different fertilizer management scenarios. By comparing maize grain yields from field experimentation (LR and SR 2011 seasons) and DNDC model simulations, the following questions are addressed; how close do field-derived grain yield values compare to DNDC derived values, given the heterogeneity in cropping systems, are default DNDC in-built values for soil nutrients and other biophysical parameters suitable for fertilizer verification studies in western Kenya, and how significant is weather data, mainly approximated for large spatial areas in Kenya, to DNDC-derived yield values when compared with field-derived yield values? Generally, field-derived grain yield values exceed DCDC-derived values (by between 15-37 %) in four out-of six fertilizer management scenario's considered. By replacing DNDC default values with established values for various soil carbon, pH, texture, clay fraction, bulk density, slope and N-concentration in the region, model- derived yield values approximate (r^2= 0.82) field-derived values quite well. DNDC simulations using localized (Kenya Metrological Department) weather data resulted in high (50–143 %) grain yield margins when compared to simulations from point derived weather data (MarkSim, DSSAT weather file generator). The DNDC model has potential, with further refinement of input-model parameters,

for supplementing the often repetitive and resource-demanding field experimentation at estimating cereal grain yields under fertilizer management practices in western Kenya.

Soil and potato nitrogen status and use of the SPAD meter in nitrogen management in Kenya

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Potato is a major crop in the Kenya with it production being in the highlands. The production area is increasing as a result of people stopping growing of other crops and opting for potatoes. The production is, however. lower than what is expected due to several challenges, one among them being the poor fertilizer management. A survey conducted to find the fertilizer use indicated that 78% of farmers use fertilizer and 90% of those using the fertilizer applied below the recommended rate of 80 kg of nitrogen (N) per ha. However the leaf samples from the farmers field indicated only 42% of farms were below the 4.5% N level in the leaves. The differences could be explained by the use of foliar fertilizers and also adequate nitrogen level as indicated by the soil analysis from the same farms. A split-plot experiment has been conducted at the university of Nairobi Kabete Campus Farm using Asante and Tigoni potato varieties with three NPK fertilizer levels (45, 90, 135 N kg/ha) and a control with no fertilizer application. The aim of the experiment is to relate the critical nitrogen curve to the chlorophyll meter (SPAD) reading. Correlation between total nitrogen and the SPAD readings from preliminary result is 0.36 while a probability of <0.001 for the means of the above ground dry matter at 0.05 significance level. The correlation between total nitrogen and SPAD reading means that farmers can use the instrument in nitrogen fertilization management.

Effect of arbuscular mycorrhizal fungi inoculation on ex-situ colonisation and performance of maize and common bean in the Kenyan highlands

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Crop plants form symbiotic association with mycorrhizae fungi and it's widespread in a natural ecosystem. Arbuscular mycorrhizal fungi (AMF) is the most important in agriculture and has received attention as part of an increasingly popular paradigm that considers an active and diverse soil biological community as essential for increasing the sustainability of agricultural systems. However, most of agricultural practices have a negative impact on AM association and agricultural soils are AMF impoverished. Interventions to replenish AMF include re-introduction through inoculation or manipulation of existing AMF to increase density. A major problem with inoculation is that there is possible competition with native (indigenous) AMF species. Indigenous AMF are more adapted to the soil environment than introduced strains but with conflicting results on the effects of AMF inoculation on crop yield, more field studies for different ecological areas are required. The objective of the study was to compare use of indigenous AMF species with other soil fertility amendment practices on subsequent colonisation and performance of maize (*Zea mays* L) and common bean (*Phaseolus vulgaris* L). Analysis was also done on the best soil amendment practice that encourages utilisation and conservation of AMF. This was tested under field conditions and compared with control treatment (no soil amendment practice) and four other soil fertility amendment practices used singly or in combination with AMF; (1) mavuno (macro- and micronutrients and secondary nutrients) fertilizer, (2) Calcium Ammonium Nitrate (CAN) and Triple Super Phosphate (TSP) (3) cattle manure and (4) minjingu (rock phosphate fertilizer with high phosphate content of about 28-32%). Maize and bean performances were determined and compared between the treatments for a period of two continuous cropping seasons with the experiment replicated in two benchmark sites of Embu district (highlands of Central Kenya) and Taita-Taveta district (coastal midlands). Soils at Embu have high soil pH than at Taita which results in low phosphorus levels and possible micronutrients deficiencies. When applied singly, AMF inoculation improved growth of beans by 51% and where else a 9% reduction in maize yield was recorded. The application of AMF combined with manure significantly ($P \leq 0.05$) improved bean yield, 93% increase was recorded compared to control treatment while with inorganic fertilizer a 58% increase was recorded. Application of AMF combined with phosphate fertilizer recorded the highest colonisation intensity of 67.72% in maize while in beans, AMF combined with minjingu and CAN recorded the highest colonisation intensity of 74.68%. Different soil fertility amendment practices in beans recorded significant difference ($P \leq 0.05$) in root colonisation intensity by AMF whereby no significance difference was recorded from similar treatments under maize. Comparable results were obtained from the two sites and crops with the highest value of AMF colonisation intensity recorded from treatment under manure and the lowest from control. Thus manure was found to be the best soil fertility amendment practice that encourages high utilisation and conservation of indigenous AMF species. Also, the positive effect of indigenous AMF inoculants indicates the potential as a complimentary input to inorganic fertilizer.

Impact of trees on water and nutrient dynamics in smallholder maize-based farming systems in Western Kenya

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Growing trees is different from other farm enterprises because the tree exerts an influence for a longer period at a considerable distance and depth away from where it is planted. Despite decreasing land size due to fragmentation, smallholder farmers continue introducing trees on their farms in a measure to optimize farm productivity in meeting their livelihood. This has resulted in a number of agroforestry practices including different or similar tree species, at varying age and density, which presumably have different contribution to agroecosystem in terms of competition, complementarity or balanced off overall

effects on below and above ground resources necessary for crop growth and productivity. In order to understand these complex interactions process-based models become essential. An assessment of local knowledge and measurement of water and nutrient dynamics in maize (*Zea mays*) and 6 selected tree species; (*Callindra calothyrsus*, *Sesbania sesban*, *Grevilea robusta*, *Eucalyptus* spp, *Croton macrostachyus* and *Markhamia lutea*) intercrop in Kitale, Trans Nzoia district, Kenya will be carried out. The study will test the following hypothesizes: (i) Agroforestry practices for predominant tree species are based solely on the farmer's perception of their competition for soil water and nutrients with associated crops, (ii) Farmers have valuable knowledge about trees and their attributes that influence soil biological activity, availability of soil water and nutrients, and crop performance, (ii) Decisions on tree management by farmers result from their cumulative experience on the variation associated with age, density and spatio-temporal arrangements of individual trees, (iii) The microclimate effect created by trees in agroforestry systems generates positive impacts on soil water and nutrient availability, soil biological activity and improves the growth of associated crops, (iv) Agroforestry systems within smallholder farms favors greater soil C storage than cropping without trees, (v) Dominant tree species significantly influence the spatial and temporal variation of arbuscular mycorrhizal fungi (AMF) abundance and diversity, (vi) AMF presence in smallholder agroforestry systems has a direct influence on soil structure, soil water holding capacity and C sequestration (vii) Future crop production by smallholder agroforestry systems can be predicted and is dependent more on the tree species introduced and management practices (e.g. spatial-temporal arrangements) than on tree age and density. (viii) Tree-crop interactions will predictably influence the spatial and temporal distribution of soil organic C, water and nutrient availability and biological activity. Measurements to be conducted on farms with comparable agroforestry plots of different ages will include maize grain yield, crop and tree biomass, AMF abundance and diversity, and abiotic (soil nutrients, water and carbon). Tree and crop parameterization will be done and simulations run using Water Nutrient Light Capture in Agroforestry Systems (WaNuLCAS) model to investigate the impact of different land uses and agroforestry practices on water and nutrient resources in the study area. The study will aid farmers and policy makers in accurately predicting the period of viable intercropping with trees and their effects on soil resources. It will also support better decisions in consideration of anticipated increased tree-crop interaction, its effect on maize production, water, nutrient availability and AMF.

Building future integrated soil fertility managers: Incorporating school-centered approach with Farmer Field Schools

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To address rural poverty in Africa, current farming practices are demanding new approaches that can integrate farmers, particularly future farmers, in learning about ISFM practices. The new approaches will have a mandate of transferring ISFM technologies, support learning, assist farmers in problem solving and enable future farmers to become more actively embedded in soil fertility management and agricultural development. Recent initiatives to mainstream extension approaches have used Farmer Field School (FFS) approach to train famers on soil fertility management. There is a large body of literature indicating that FFS approach is vital for technology innovation, promotes knowledge sharing, reinforces community learning and accelerates adoption of technologies. The FFS approach however has not involved children (future farmers) in learning new soil fertility management practices. This paper outlines a novel approach that integrates FFS principles and provides a framework to involve students and their parents in learning ISFM practices to improve the livelihoods of rural families in Eastern Uganda. The approach, School Centered Community Development Approach (SCCDA) involves school children in experiential learning with their parents. The SCCDA borrows several principles of FFS except that the learning is conducted within school community with full participation of the community and the students and emphasizes on putting children first. It focuses on building and strengthening children's ISFM knowledge and interests, with parents as facilitators of learning. It also allows children to actively participate in discovery learning processes with a variety of hands-on field activities that promote successful learning of soil fertility practices. Through the SCCDA, farmers ISFM learning processes are greatly enhanced and passed on to children who will become future farmers. The SCCDA acknowledges the role of children as future farmers and agricultural experts as central to improving soil fertility in Uganda. We argue that with information provided, it will spur more to join the agricultural fields as experts and those who go into farming to practice proper agronomic techniques and also demand for quality advisory services and information because they have some background knowledge. We conclude that by incorporating the principles of farmer field schools into the School Centered Approach, we can start building a cadre of young future farmers who will learn alongside their parents and go a long way in imparting skills and enhance ISFM activities that can meet tomorrow's agricultural challenges in eastern Africa

Towards improvement of fertilizer recommendations: assessment of crop limiting nutrients and appropriate nutrient rates

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In order to achieve the Millennium Development Goal of halving the number of people suffering from hunger in Africa, the African Green Revolution (AGR) initiatives target a substantial increase in crop production from the current cereal yields of about 1 t/ha to 3 t/ha. While it is generally recognized that the success of the African Green Revolution depends on increased use of fertilizers and improved germplasm, fertilizers uses in many parts of sub-Sahara Africa are based on blanket recommendations both for the type and the quantity of fertilizers. Given the wide diversity of soils and farming systems, the use of such blanket

recommendations at national or regional level often results in low efficiency of fertilizers. Nutrient omission trials and N response trials were conducted in 10 km x 10 km grids in Kenya, Tanzania and Uganda to identify limiting nutrients and to determine the appropriate N application rates for maize crop. The nutrient omission trials were conducted in 16 fields per grid and include 10 treatments: a Control treatment with no nutrients added, a treatment with the application of the 3 major nutrients N, P, and K (NPK treatment), 3 treatments in which N, P, and K were omitted from NPK treatment one at a time, a treatment with S added to NPK, a treatment with multinutrients (Ca, Mg, S, micronutrients) in addition to NPK, 2 treatments in which K is not applied but S or S and Zn were added, and one optional treatment in which lime is added to NPK. Nutrients were applied at non limiting rates.The N response trials were conducted in 8 of the fields used for nutrient omission trials per grid and include five N rates (0, 60, 90, 120, 150 kg/ha) replicated 3 times per field. In Ruhiira, Uganda, averages maize grain yields of the NPK treatment were reduced by at least 600 kg/ha in all treatments that did not receive K, making K as the most limiting nutrient for the site. Adding multinutrients did not improve the yield of NPK. In Mbola, Tanzania, the addition of sulfur or micronutrients increased the NPK yields by about 1t/ha, whereas there was no significant change from the omission of any of the nutrients compared to NPK. The N response trials indicated that about 90 kg/ha is sufficient to increase the yields to the level targeted by the AGR. Although the 3 sites considered in this study have currently the same fertilizer recommendation, DAP and Urea, the results show that they require different nutrients, some of which (K and micronutrients) are not supplied by the current fertilizers. The integration of soil parameters, and management information will further provide an understanding on the occurrence of nutrient deficiencies.

Variation of soybean varieties in nitrogen fixation and management of *Striga hermonthica* in Western Kenya

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The emergence and persistence of parasitic *Striga* spp. threaten to wipe the entire host crop yields in developing nations and beyond. Nutrient depleted soils with low organic matter content and nitrogen provides a favorable environment for *Striga hermonthica* infestation. Soybean is a key legume for Vision 2030, as it meets multiple needs at multiple scales and it complements both organic and inorganic fertilizers in Africa. The mode of action of different soybean varieties is variable in stimulating suicidal germination of striga seeds and increasing biological nitrogen fixation (BNF). Therefore, this multi-locational trial was set in three Districts of western Kenya (Bondo, Siaya and Teso) using 30 replicates (farmers used as replicates, 10 per District and 5 per Sub-location) to evaluate the potential of four Soybean varieties; Early (SB4), medium (SB8) and late maturing (SB18, SB20) for managing the striga seed bank and improving soil nitrogen status in different agro-ecological zones (AEZ). Increasing legume production through grain yield and matching these legumes to their correct AEZ is an important component for enhancing agricultural systems in the tropics. Well-adapted and preferred varieties will provide an alternative option to resource-limited small-scale farmers. The preliminary results of changes in striga seed bank, nodule biomass at 50% podding and grain yield across seasons will be discussed and presented.

Can integration of trees and crops contribute to enhance agricultural productivity, resource utilisation and livelihoods for smallholder farmers?

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Agricultural production in East Africa is stagnant or declining while there is a population growth which has resulted in shortage of land and food insecurity. Increased pressure on natural resources, including deforestation, is also increasing the vulnerability of smallholder farmers to climate change, often manifested as rainfall variability and water scarcity. Low input of mineral fertiliser and manure has led to nutrient mining and reduced soil fertility. In order to improve productivity and livelihoods in the long run, the declining trends in soil fertility and tree cover need to be reversed and the resilience of the farming systems to climate variability and other stress factors enhanced. More trees on farms and in agricultural landscapes are needed to produce firewood, timber, fodder, fruit, etc. and to deal with environmental problems caused by deforestation. There is an expressed interest in farming systems with intercropping of trees and crops, in combination with livestock for eggs, milk and meat, so called agroforestry systems. The main research question in this project is: *Can integration of trees and crops, and often livestock, contribute to enhance agricultural productivity and resource utilization, and contribute to improved living conditions for smallholders?* We are using a quantitative approach to assess the productivity and multifunctionality of agroforestry systems at different scales applying available modelling tools. The aim is to quantify the biomass production, carbon storage and nutrient flows on field, farm and landscape levels in western Kenya. Five settlements with similar soil and climatic conditions and with well documented land use history have been selected in the Kitale area. At the field scale, the WaNuLCAS (Water, Nutrient and Light Capture in Agroforestry Systems) model that includes competition between trees and crops for light, nutrients and water is being applied. Six different tree species (three native and three exotic) have been selected and the competition between trees (of different size/age) and maize is being studied on farmers' fields. In addition an on-station trial with different trees species is presently carried out to evaluate tree-crop interaction. At farm scale the NUANCES framework (Nutrient Use in ANimal and Cropping Systems - Efficiency and Scales) will be used to study flows of nutrients and other resources on farms with increasing complexity; crops, crops and trees, crops and livestock, crops and trees and livestock. One farm of each farm type has been selected in the five settlements (in total 20 farms) and data is collected through interviews, field surveys (e.g. number of trees and tree species), measurements (e.g. crop performance), sampling and analyses (e.g. soil carbon, nutrients, aggregate stability).

At the landscape level, a GIS-based modeling tool (Polyscape) will be explored to study the contribution of trees to synergies and trade-offs between agricultural productivity and other ecosystem services (water and sediment flows, contiguous habitat, development of carbon storage). Preliminary results from ongoing studies will be presented and discussed.The work builds on established partnerships and networks and includes two PhD projects. The project involves researchers and students from Sweden and Kenya, and it aims to develop good cooperation and communication between research, education and extension.

Impact of soil fertility management practices on major insect pests of beans and yield in Taita District, Kenya

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The common bean is an important food and cash crop in Africa. It provides food for more than 100 million people and is a critical and a growing source of income for rural households. Common bean yields, however, have dropped in the last ten years by as much as 50 percent. This decline is attributed in part to high incidences of insect pests; key among them being the bean stem maggot (*Ophiomyia* spp.) and the black bean aphid (*Aphis fabae*). To overcome the insect pest problems, insecticides were and are still used. However, problems have arisen, some quite serious to detract from the benefit realised from insecticides. This is related in large measure to the fact that ecological considerations have been essentially ignored in the development of these materials and chemicals; instead toxicological and economic criteria have been used. This study aimed at assessing alternatives to the use of insecticides in controlling levels of infestation of *Ophiomyia* spp and *A. fabae* and their impact on beans yield. Field trials were undertaken in Taita district where agriculture contributes to 95% of household income with very little or no fertility inputs in farms. In the study the following were tested: two kinds of fertilizers, farmyard manure and *Trichoderma* seed coating. Planting was done during the long rains. Field survey of *Ophiomyia* spp and *A. fabae* were conducted four weeks after bean emergence and at harvest to determine their incidence and prevalence. Plant mortality, plant survival, and yield were used as criteria for assessing crop loss. The addition of soil amendments had no influence on the levels of infestation of the bean stem maggot and the black bean aphid, and their associated plant mortality. Notwithstanding, soil fertility management positively influenced yield parameters such as the number of pods per plot, dry-seed, and bean-straw. Three treatments, namely Mavuno + *Trichoderma*, TSP + CAN and Mavuno were able to improve yield by 52.9, 48.9 and 46.7% respectively.

Scaling-out soil fertility amendments in western Kenya

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Alleviation of low soil fertility is an important step to improving smallholder agricultural productivity in western Kenya. Past research has yielded several proven technologies for soil fertility management, including use of organic and inorganic inputs that can increase maize yield, the staple food crop, from 0.5 t ha^{-1} to 4.5 t ha^{-1}. In 2010, Kenya Agricultural Research Institute, with financial support from AGRA, initiated a project to disseminate and promote adoption of these technologies. At the initiation of the project, a baseline survey was conducted to provide benchmarks for *ex post* impact assessment and insights on factors that are likely to influence adoption of selected soil management technologies in four districts in western Kenya. Data were collected from a random sample of 327 households using a structured questionnaire and analyzed by descriptive statistics and binary logit model. Results showed that factors which influenced adoption varied by soil amendment technologies. The factors which had positive and significant effects ($p \leq 0.05$) on adoption of inorganic fertilizers were education level of household head, membership in groups, access to off-farm income and location of the district in a high agriculturally potential area, whilst distance to major markets and gender of the household head had significant mixed effects on the adoption of manure and inorganic fertilizers. Households which owned cattle were most likely to adopt manure. Understanding these factors is important in targeting different soil amendments to farmers during the next project cycle, which focuses on moving beyond the demonstration plots by facilitating farmers' access to inputs and output markets. Furthermore, this paper discusses lessons learnt in scaling-out technologies beyond demonstration plots and suggests a way forward to enhance the adoption.

Agronomic and financial analysis of maize-legume inter-cropping systems in western Kenya

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In Kenya, 80% of the extreme poor live in rural areas and rely on smallholder agriculture for their livelihoods. Sustainable intensification of agriculture has thus gained support because of the growing recognition that improved farm productivity is a major entry point to break the vicious circle of rural poverty. Maize and grain legumes are the dominating enterprises in western Kenya. Whilst maize provides the backbone to food security, grain legumes are multi-functional sources of household protein, fix atmospheric nitrogen to the soil and provide livestock feed. Yield of maize on smallholder farms is typically 0.5 t ha^{-1} compared to about 7 t ha^{-1} obtainable under research. The low yields in western Kenya have been blamed on low soil fertility and parasitic striga. Against this backdrop, during long rain seasons in the years 2010 and 2011, a total of 24 on-farm demonstrations were set up in four districts in western Kenya using a Randomised Complete Block Design (RCBD) involving four treatments: 1. Maize-bean, 2. Maize-soyabean, 3. Maize-desmodium and 4. Maize-groundnut intercrops. Recommended fertilizer rate and spacing were applied. The aim of the demonstrations was to disseminate Integrated Soil Fertility Management (ISFM) technologies that could improve crop yields. The objectives of this study were twofold: to evaluate the effect of different

maize-legume intercrops on maize and legume grain yields; and to analyse costs and benefits of the maize-legume intercrops. Data were collected on maize and legumes yield parameters as well as on quantities of inputs applied, especially labour and soil nutrients and prices of both inputs and outputs. The data were evaluated by Analysis of Variance (ANOVA) using an unbalanced design and means separated by the least significant difference (LSD), and by cost-benefit analysis. Results show that the highest maize grain yields (4.8 t ha^{-1}) were obtained from maize-bean, followed by maize-groundnut (4.7 t ha^{-1}). However, the yield of maize varieties varied by districts but there was no significant differences in treatments. Amongst the legumes, soyabean gave highest grain yield (0.5 t ha^{-1}). The highest benefit-cost ratio of 2.6 was obtained from maize-bean intercrop and the lowest (1.6) was from maize-soybean. This was mainly because beans had the highest demand and market price per unit compared to other legumes. The findings of this study point to the need to develop policies that promote smallholder farmers' access to efficient input and output markets.

Influence of phosphorus on selected soil properties dynamics in a desmodium-maize based cropping system in Western Kenya

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Incorporation of herbaceous legumes in cereal-based cropping systems is currently picking up amongst small households in western Kenya. In particular, some desmodium species have been popularised for improving soil fertility and for controlling both stem borer and parasitic striga. However, low P level in the soil inhibits prolific legume growth thus necessitating addition of starter inputs in order to realise optimum benefits from such legumes. We initiated a field experiment at Ndori and Ngiya to determine the effect of two desmodium species on seasonal soil fertility dynamics at different P regimes. A 2 x 4 factorial experiment was laid on a randomized complete block design in 3.75 x 3.3 m plots. The two factors were desmodium species (*Desmodium uncinatum* and *D. intortum*) and phosphorus rates (0, 23, 46 and 69 kg P_2O_5 ha^{-1}). The treatments were replicated four times. One maize (H 513 variety) $plant^{-1}$ hill was maintained in a 75 and 30 cm inter and intra-row spacing respectively. Desmodium seeds were drilled between rows of maize at the rate of 2.5 kg seed ha^{-1} . A blanket dose of N (urea) was applied at 20 kg ha^{-1} in two splits (33% at planting and 67% at 6 weeks after planting). Selected soil properties (soil pH, organic carbon, total N, P and CEC) were seasonaly monitored for four continuous cropping seasons. Data was subjected to ANOVA and significantly different means separated by LSD at 5%. Results showed that soil pH was reduced by 0.26 and 0.11 units in Ndori and Ngiya sites respectively. Application of phosphorus at 46 kg P_2O_5 ha^{-1} not only significantly retarded N losses compared to the control treatment but also increased soil organic carbon to 0.2% while application of fertilizer at 69 kg P_2O_5 ha^{-1} in Ngiya increased SOC to 0.25%. The corresponding increases in SOC at Ndori were 0.15% and 0.2% at 46 and 69 kg P_2O_5 ha^{-1} respectively. There was no significant change in either potassium or magnesium levels after the four seasons. Seasonal CEC trends are also discussed.

Establishing the most limiting major nutrient in two soils within the semi-deciduous forest zone of Ghana based on maize growth and yield

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Applying Liebig's law of minimum to soil fertility management is an effective way of increasing crop yield. A study was conducted on acidic soils at Assin-Kushea (5° 87' N and 1° 45' W) and Twedie (6° 65' N and 1° 74' W), both within the semi-deciduous forest zone of Ghana, to identify between N and P, the most limiting major soil nutrient to maize yield. In each site, four soil amendments (120 kg N ha^{-1}, 90 kg P ha^{-1}, 120 kg N ha^{-1}+ 90 kg P ha^{-1}, and no amendment control) were replicated thrice in a Randomised Complete Block Design. Treatment effects were evaluated on sole-cropped maize (Dorke) field trial. Soil organic carbon, total nitrogen, available phosphorous, ECEC and base saturation were higher at Twedie (loam) than Assin-Kushea (loamy sand). Plant height differed consistently from 3 to 7 weeks after planting, with $N_{120}P_{90} > P_{90} >$ control $> N_{120}$ at Assin-Kushea. The trend for maize height at Twedie was $P_{90} > N_{120}P_{90} >$ control $> N_{120}$. Maize height showed a wider range at Assin-Kushea (from 23.77 to 208.22 cm) than Twedie (from 21.01 to 147.15 cm). The maize stover yield followed similar trend at both sites with $N_{120}P_{90} > P_{90} > N_{120} >$ control. While the range for stover yield was 2.14 to 3.37 t ha^{-1} at Twedie, it was 2.44 to 4.90 t ha^{-1} at Assin-Kushea. At Assin-Kushea, maize grain yield ranged from 1.24 to 2.44 t ha^{-1}, with increases over the control in the N_{120}, P_{90} and $N_{120}P_{90}$ treatments of 10%, 77% and 95%, respectively. However, the maximum and minimum values for indices of agronomic efficiency and nutrient use efficiency, as well as for harvest index, were obtained in the P_{90} and N_{120} treatments, respectively. Furthermore, while N uptake by maize grain was similar for all treatments, P uptake was significantly higher in P_{90} and $N_{120}P_{90}$ than in control and N_{120} treatments. The value cost ratios due to P_{90} and $N_{120}P_{90}$ at Assin-Kushea were 6.73 and 5.85, respectively (indicating that their application is economically viable), while N_{120} gave a negative return on investment. Phosphorus was therefore the major plant nutrient limiting maize growth and yield at both sites and should be externally supplied to enhance maize production in these and similar soils.

Effects of selected soil and water conservation techniques on rainfall use efficiency and maize productivity in the Central Highlands of Kenya

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Small-scale farmers under rain-fed agriculture in Sub-Saharan Africa have recently experienced declining crop yields linked to unsustainable soil management practices and erratic rainfall attributed to climate variability. Appropriate soil and water conservation practices can conserve soil nutrients, improve rainfall use, mitigate dry spells and increase crop yield levels. Four alternative *in situ* rainwater conservation practices; tied ridging, minimum tillage, intercrop and mulching were evaluated for two consecutive cropping seasons in two contrasting experimental stations in the central highlands of Kenya; Machang'a in Mbeere South District and Kigogo in Meru South District. Influence of the technologies on maize performance and relationships of rainfall and runoff on maize fields were evaluated. About 18–35% of the seasonal rainfall resulted in runoff when maize was grown without water conservation, whereas the conservation practices resulted in significantly low runoff. Tied ridging in Machang'a and mulching in both sites increased available soil water by more than 15% compared to control treatment. Mulching also increased the grain yield by 53% in Kigogo and 86% in Machang'a during good harvest season. Tied ridging and minimum tillage increased grain yield by 79% and 3.4% in Machang'a and Kigogo, respectively. Intercropping. however, suppressed grain yield significantly ($p=0.05$) in both sites. Water being the most limiting factor in semi-arid area of Machanga, we recommend tied ridging and mulching as best soil and water conservation options to mitigate effect of drought stress in maize while minimum tillage and mulching technologies for the sub-humid region of Kigogo.

The effect of tillage, crop residue application and crop rotations on soil organic matter dynamics and soil microbial biomass in western Kenya

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The effect of reduced tillage verses conventional tillage, crop residue (maize stover) application and crop rotations were investigated on a long-term conservation tillage trial on an Oxisol in western Kenya. The experiment was established in 2003 as a split-split-split plot design involving a factorial combination of tillage systems in the main plots [reduced tillage (RT) and conventional tillage (CT)], and crop residue management in split plots (plus and minus crop residue). Cropping systems were superimposed in split-split plots (continuous cereal, rotation and intercropping) and nitrogen (N) or phosphorus (P) in split-split-split plots. Reduced tillage and crop residue application had a significant effect ($P<0.01$) on total soil organic carbon and potentially mineralizable carbon. Tillage and crop residue application also had a significant effect ($P<0.01$) on soil microbial biomass. However, the type of cropping system had no significant effect on soil organic carbon and microbial biomass. The study shades more light on factors that need to be given more weight in the implementation of conservation agriculture practices especially under resource-constrained smallholder farming systems.

Will ISFM alone realize the green revolution for Africa?

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Green Revolution for Africa is a major concern in the continent and elsewhere that required tackling sometime back for Africa to be able to feed itself and sell the surplus. This view was further strengthened by the African Heads of States summit meeting in Abuja in 2006. A Green Revolution refers to a series of research, development, and technology transfer initiatives occurring between the 1940s and the late 1970s. The initiatives, led by Norman Borlaug, involved the development of high-yielding varieties of cereal grains, expansion of irrigation infrastructure, modernization of management techniques, distribution of hybridized seeds, synthetic fertilizers, and pesticides to farmers. In this matter and specific to Africa, there have been numerous attempts to introduce the successful concepts from the Mexican and Indian Green Revolutions into Africa with little success. There are many reasons advanced for this failure and this paper attempts to analyze the driving factors while also introducing a spin into the debate like the one introduced by Horward Buffet as to whether Africa really requires a green or brown revolution. According to him, a "Brown Revolution" to improve soil quality was more important to African agriculture than new seeds and fertilizers. "Simply distributing seeds and fertilizer, if that's the plan, will fail long term." Howard's concept of a brown revolution is almost akin to ISFM though not quite there since ISFM advocates more than just seeds and fertilizers. We are of the view that there is more to it than just the brown revolution if we are to overcome hunger and realize food security on the continent. We attempt to answer this question by analyzing several factors that revolve around: research data availability, cultivated land sizes, cropping densities, fitting technologies, finance, inputs, markets, institutions, culture, infrastructure, communication, mechanization, policy and politics. We have used data collected by the AfSIS project in Western Kenya and Nigeria including analyzing published material on the subject matter. Our conclusion is that we need to critically go back to Norman Borlaug's concepts and expand these while being further sensitive to geographic disposition, economic ability, including individual country infrastructure. The paper offers Africa's governments and development managers an insight with a fresh view on what could be missing from the puzzle.

Impact of ICT in maize cultivation and agronomy: The case of the short text messages service to farmers in Western Kenya

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Debates on lack of research impact of agricultural interventions on the African continent are replete and is of major concern to many researchers as well as rural development donors and governments. Several methods of extension are practiced that carry technological innovations and interventions to farmers. Examples include the Training and Visit method, Farmer Field Schools, as well as the demand-driven approach. Despite the efforts being made, a major challenge that persists in all these models and approaches is the one that relates to reaching required numbers of farmers with information they require during the crop season. The aim of this paper is to show that ICT through the use of mobile phones has the benefit of reaching a critical number of farmers and other stakeholders at much lower costs, in a timely manner while meeting the objective of increasing the farmer's productivity. The study was conducted in the North Gem location of Nyanza province of Kenya during the long rains of 2012. The activity was a combined effort of the Africa Soil Information Service (AfSIS) project of CIAT, the African Soil Health Consortium Project coordinated by CABI and Fibrelink Communications Limited, a private company specializing in ICT communication. The messages sent to the farmers included messages on the correct type of maize seed, type and amount of fertilizer to apply, how to space the maize crop, when to weed, how to protect maize crop from pests and diseases, where to place soil conservation measures, as well as how to get their soils analyzed. Farming activities were followed during harvest in the month of August in the same year and the yields measured on 3x3 m maize plots. 50 farmers receiving the text messages and 50 farmers not receiving the text messages were sampled. By measuring yields of farmers receiving SMS messages and those not receiving the messages, we found that farmers receiving the text messages doubled their maize yield compared to those who did not receive the same text messages. This method of reaching the farmers is a breakthrough approach since apart from the farmers meeting the costs of receiving the text messages, they get timely information and the service providers are able to create business models out of the service that is more sustainable in the short and in the long run.

Effectiveness of liming and phosphorus fertilizer on maize production in acid soils of Western Kenya

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Africa is the only continent where, year after year, the number of those affected by food insecurity is on the increase. Smallholder farmers (95% of the total population) in western Kenya have persistent low yields (<1 t ha^{-1} $season^{-1}$ maize and <0.5 t ha^{-1} $season^{-1}$ legumes) in comparison to the potential estimates of 6–8 t $ha^{-1}season^{-1}$. Soil acidity is a major contributor to soil infertility in this region and it limits crop production on 30–40 % of the world's arable land. Liming, one of the interventions recommended to ameliorate soil acidity, is hardly practiced in the region where acid soils occupy about 0.9 million hectares of land. An on farm research was conducted during the 2010 long and short rains in selected sites (Kakamega & Ugenya districts) to evaluate direct and residual effects of various lime sources on phosphorous availability and maize yields. This comprised of agricultural lime from Koru, (20.8% CaO) and Athi River, (45% CaO), Minjingu phosphate rock (MPR) (38% CaO, 29% P_2O_5) and Mavuno fertilizer (26% P_2O_5, 10% N, 10% CaO, 4% MgO, 4% S_2O). Triple superphosphate (46% P_2O_5), supplied P to the two agricultural limes. To achieve the research objectives, two separate experiments were carried out. The first experiment used the two agricultural limes to evaluate maize yield response and P availability to a combination of lime and P fertilizer. The second experiment tested the effectiveness of the four liming and P fertilizer sources on P availability and maize (variety H513) yields. Results indicated significant ($p<0.05$) responses of maize yield to the soil amendments material applied. Application of lime alone increased maize yield above the control in all the sites. In the first experiment, lime applied at 1.5 t ha^{-1} + 26 kg P ha^{-1} gave the highest yield of 4.65 t ha^{-1} (Ugenya) and 3.76t ha^{-1}(Kakamega North). Maize grain yield increased from 2.06 (control) to 6.21, 5.19, 4.59 and 3.92 t ha^{-1} (Ugenya), and 2.08 (control) to 4.47, 3.78, 4.27, and 3.29 t ha^{-1} (Kakamega North) where Mavuno, Koru, Athi lime and MPR were applied respectively in the second experiment. The high yield given by Mavuno fertilizer could be due to the additional nutrients it contains. Addition of micronutrients, when targeted to deficient soils improves on the uptake of macronutrients. The highest external P use efficiency was given by Mavuno fertilizer with a value of 119 kg grain kg P^{-1} applied in Ugenya district, while Koru lime + TSP had a value of 49 kg grain kg P^{-1} applied in Kakamega North district. Application of lime increases maize yield above the control, however, the yield is optimal when nitrogen, phosphorus and micronutrients are included.

Farmers' coping mechanisms and effectiveness of inorganic fertilizers on *Striga hermonthica* control in maize cropping systems of eastern Uganda

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Maize is an important cash crop and staple food for smallholders in maize-mixed farming systems in sub-Saharan Africa. However, its production is often constrained by *Striga hermonthica*, a parasitic weed cereals. *S. hermonthica* is present in Uganda with severe infestation intensities observed in eastern Uganda in areas associated with poor soil fertility status especially

in N and P. To this effect, research is being conducted in Tororo and Busia districts of Uganda to establish farmers coping strategies for managing striga and to determine effectiveness of fertilizer application in maize varieties; WS 303 (IR-maize) and Longe 5 maize on striga infestation levels, seed-bank intensity, nitrogen use efficiency and grain yield. Methods employed in the research include household surveys and researcher-managed experiments. The survey will generate farmers' awareness, attitudes, perceptions and coping strategies for *S. hermonthica* management and assess severity and incidence of striga infestations. The first sets of experiments were initiated during the long rains of March–June/July (2012A) and will be repeated during the short rains of August/September–December, (2012B). The treatments applied are two levels of Nitrogen (N) at 0 and 50 kg N ha^{-1} on fields of high and low fertility, and phosphorus (P) and potassium (K) fertilizers were applied at blanket rates of 30 kg P ha^{-1} and 60 kg K ha^{-1} respectively. The preliminary results of striga counts data collected so far indicate higher infestation in Busia than in Tororo. This work is intended to improve productivity of maize cropping systems through combined use of farmers' control coping practices and improved agronomic practices of using inorganic fertilizers and improved maize germplasm. Finally, researcher-farmer led evaluations will lead to the making of acceptable recommendations based on the prevailing farming conditions.

Seasonal variation and vertical distribution of mycorrhiza of *Pinus caribaea* in Uganda

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It is important to know which period favors or limits the activity of mycorrhiza as regards temperature and moisture level. This makes it easier to know which season it is best to do planting out to give initial advantage to the seedlings. Also it becomes easy to determine when to take forest soil inoculum for preparing nursery soil. The roots of pines consist of short and long roots, the former being mycorrhizal and the later non-mycorrihizal. The proportion of the two types of roots do, however, vary somewhat with soil condition and depth. It is therefore necessary to know in which type of soil and at what depths the intensity of mycorrhiza is greatest. This helps when collecting soil inoculum from the forest. Soil samples were collected from *Pinus caribaea* plantations for three months. Soil fractionation was carried out in the field and mycorhizal counts done in laboratory. Mycorhizal intensity is greatest in wetter months. It is less on the top of the soil, rises from two centimeters to four centimeters then decreases steadily with soil depth. Mycorhiza is more active in soils with high moisture. Top soil has undecayed needles of pines with less moisture and nutrients. The humus layer (two to four centimeter depth) has high moisture and nutrients necessary for mycorhizal growth. Soil temperature rises and soil becomes less aerated with depth. Seedlings are planted out in rainy seasons and soil inoculation should be taken at this time from the humus layer.

Mycorrhizal fungi of Malian soils

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Mycorrhizal symbiosis are now well known in most of West African countries but in Mali, studies on these microorganisms remain the poor parent of microbial ecology. In fact, in Mali, data are still scarce and neglected. The aim of this study is 1) to present the mycorrhizal state and diversity of Malian soils, 2) to evaluate the degree of root colonization and 3) to compare their rate colonization with strains isolated from Senegalese soils as *Glomus aggregatum*, *Glomus intraradices* and *Glomus eticulatum*. For this purpose, soil sampling was comducted under different plants: sorghum, rice, maize, forest trees, tomatoe and salada. Experiments were conducted for 4 months in the greenhouse of the Soil Microbioloy Laboratory at the Faculty of Sciences and Technics of Bamako. The different soils were put in bags in rate of 1 kg per bag and sorghum was chosen as a trap plant. After three months of culture, preliminary results showed that Malian soils contain a high diversity of arbuscular mycorrhizal fungi. But despite of this high AM fungal diversity, root colonization was less than those of Senegalese strains for all soils sampling in Mali. Therefore, the mean of roots colonization in Malian soils showed a colonization rate of 64% under coton plants and 46% under rice. Mycorrhization for Senegalean strains varied between 60% and 70%. It is important to make other investigations to confirm these observations.

Water use efficiency of selected under-utilized indegeneous vegetables as affected by seed density and spacing

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Selected under-utilized indigenous vegetables (UIVs) were cultivated under different spacing and seed densities as part of a study to investigate the their optimum agronomic practices. Water contents of the soil was monitored with the use of the TDR 300 (Spectrum) at incremental depths of 7.5 cm using access pipes to a depth of 45 cm. The vegetables were harvested for biomass determination every two weeks starting from four weeks after planting. The optimum spacing requirements for biomass yield was found to be different among the UIVs. Generally, the biomass yield was highest for elegede and a spacing of 0.75 m gave the optimum biomass yield for ugu (*Telfaria occidentalis*) while a spacing of 0.45m gave the optimum yield for ogumo (*Solanum* spp). The highest water use efficiency was recorded for bitter leaf (*Vernonia amygdalina*) at a spacing of 0.5 m followed by snake tomato (*Trichosanthes cucumerina*). This becomes very important in the dry season when the little water available has to be judiciously apportioned. In conclusion, the study was able to establish some agronomic baselines for the planting of these under-exploited indegeneous vegetables.

Effect of *Bradyrhizobium* inoculation and phosphorus application on soybean production in Benin

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The effect of bradyrhizobium inoculation and phosphorus application on soybean (*Glycine max* (L.) Merr.) production was studied by two years experimentation in Benin. An on-station trial was carried out at Sekou in 2007 and on-farm experiments conducted at Zado Dovogon (southern Benin) and at Yawa (centre of Benin) in 2008. Four rates of P (0, 50, 100 and 150 kg ha^{-1} of P_2O_5) were used on-station and two rates of P applied to farmers fields (0 and 100 kg ha^{-1} of P_2O_5) followed by inoculation treatments. Four replications were done on-station while six farmers' fields represent six replications at Zado and Yawa. The results revealed that inoculation with *Bradyrhizobium japonicum* indicated significant improvement on growth, nodule number and grain and shoot yield of soybean but less than combination of *B. japonicum* and phosphorus supply. The most efficient combination of inoculation and phosphorus was 100 kg P_2O_5 $ha^{-1}$for field experiment. In addition, the results also showed low root colonization by mycorrhizae in the presence of high rates of P. The supply of 150 kg ha^{-1} of P_2O_5 combined to the inoculation significantly decreased growth, nodule number and yield of soybean. This study revealed that inoculation and the provision of P provide significant benefits to the plant and can be used to improve the growth and yield of soybean in different agro-ecological areas of Benin.

Potential for changing traditional soil fertility management systems in Rhodic Ferralsols in the south of Benin

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Rhodic Ferralsols, commonly called "Terre de Barre", are reds soil characterized by increasing clay content (kaolinite) with depth. They are located in the coastal basin between 1° 30' and 2° 50' east longitude, 6° and 7° 40' N latitude at altitudes from 15 to 240 m in bimodal rainfall areas of Benin. They support more than 30% of the population and occupy only 7-10% of the soil in Benin, covering 7400 km^2. They are highly degraded due tohigh population pressure, intensive cropping with less or no financial capacity for farmers to apply chemical fertilizers, while fallow in the "Terre de Barre" areas hve largely disappeared. These soils are characterized by fragmented structure, a decrease in their organic matter content and in cation exchange capacity. Soil acidification is rising with the appearance of exchangeable Al, a failure in nitrogen cycling in these soils followed by important lack of activity of macrofauna. These poor physical, chemical and biological characteristics severely reduce the productivity of the crops. Slash and burn was a traditional practices on this type of soils for land preparation further accelerated soil degradation, the drop of soil fertility, and consequently decreasing maize yields. Organic matter of these soils is so low that the efficiency of the use of mineral fertilizer by crops is insignificant. To reverse this trend, cereal was grown on rotation to grain, cover crops and tree legumes' residues as alternatives to the use of mineral fertilizers. The field experiment described in this research concern seven herbaceous legumes residues used as soil amendments to compare their contribution on the maize yield at Avokanzoun, Benin (7° 20' 40" North and 1° 56' 00" East). These residues were as followed: *Aeschynomene histrix*, *Centrosema pubescens*, *Chamaecrista rotundifolia*, *Mucuna pruriens*, *Pueraria phaseoloides*, *Stylosanthes guianensis* and *Stylosanthes hamata*, previously planted with two rates of phosphorus (45 P_2O_5 and 0 P_2O_5) applied as Triple Super Phosphate. The following cropping season, the previous residues plots were divided in two and each part received 0 and 60 kg N applied as urea after planting maize. Maize variety (DMR-SRW, 90 days) was used and grain yield, dry matter yield and N uptake were determined. Legumes plants received a total rainfall of 669 mm in 2003 and maize plants, 599 mm in 2004. Maize grain and straw yields responded significantly to legume residues used as amendment compared to the control. Legume residues applied on the soil surface and receiving P or N fertilizers improved maize grain yields (1602 kg/ha for P and 1786 kg/ha for N) compared to mineral fertilizers applied alone (458 kg/ha). The best grain yield (1794 kg ha^{-1}) and grain N uptake (149 kg N ha^{-1}) were obtained with the use of *M. pruriens* residues. No synergy was found when combining N, P, and different residues on the maize yields. Residue incorporation resulted in extra accumulation of N by maize. The beneficial effects of residue incorporation of legumes have been attributed to the decomposition of their biomass and thereby increased nutrient availability. In conclusion, the study has shown that legumes residues incorporated in soil improve significantly the maize yield on degraded Rhodic Ferralsols.

Effects of soil ecosystem engineers on soil aggregate stability, soil C and crop yields under different tillage and residue management systems

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Agriculture in Sub-Saharan Africa needs sustainable intensification to satisfy the growing demand for food without compromising the natural resource base. However, soil fertility depletion and degradation are major biophysical causes of stagnating staple crop yields. Conservation Agriculture (CA) is promoted in SSA for its potential to stimulate soil biota and associated soil functions, thereby contributing to improvements in soil structure, water retention, soil organic matter content and nutrient dynamics as well as higher and/or more stable crop yields. Termites, ants and earthworms belong to the most important soil ecosystem engineers, but especially the role of termites in CA systems remains largely unclear.Therefore, this study aimed

to determine the effects of earthworms and termites on soil aggregate stability, soil C and crop productivity under different tillage (conventional +T; reduced -T) and residue management systems (retention +R; removal -R). A randomized block trial under maize-soybean rotation was initiated in sub-humid Western Kenya in 2003, and a macrofauna exclusion experiment was superimposed in 2005 as split-plot factor (exclusion +ins; inclusion –ins). Macrofauna abundance and diversity, soil aggregate fractions, soil carbon and crop yields were measured between 2005 to 2008 at 0-15 cm and 15-30 cm soil depths.Insecticide application effectively reduced termite ($P<0.001$) and earthworm ($P<0.001$) abundance at 0-15 cm, while tillage and residue management did not have a significant influence on macrofauna. Pseudacanthotermes sp. was by far the most abundant termite species. Conventional tillage increased aggregate stability by decreasing large macroaggregates (LM $P<0.001$) and increasing microaggregates (Mi, $P<0.001$) at 0-15 cm, while insecticide did not have any influence on soil aggregate fractions. Moreover, insecticide application did not have any significant effect on total soil C and aggregate C. Maize and soybean yields were strongly increased under insecticide application (both $P<0.001$). This might be due to the fact that Pseudacanthotermes sp. is a well-known pest species causing lodged maize plants, a phenomenon that had been observed in the –ins treatments.In conclusion, termites might be a crucial factor for the success of CA in SSA, which is not yet well understood. Future research should contribute to develop sustainable termite management that controls detrimental pest traits while conserving potentially beneficial ecosystem functions.

Cassava market integration in the Democratic Republic of Congo

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This study seeks to understand the role played by markets in the increasing food insecurity in the DRC, although the country is accounted as the second biggest producer of cassava in Africa. A co-integration model was used to test whether the cassava market is integrated in the long- and short-run to make food more available and accessible across the country. Secondary time series monthly price data of cassava were collected from the FAO data base for a period of five years (2005-2009) from 11 provincial markets and other data were collected through field survey. The results from the error correction mechanism (ECM) suggest that on average 30% of past deviations from the long run are corrected each month. Among the 11 paired markets, the highest coefficient of price adjustment in the long run was indicated by the paired markets Bukavu–Goma (43%), Mbujimayi–Kananga (38%), and Matadi-Kinshasa (36%). In the short-run, the index of market connection showed high price differential between different markets, among 11 selected markets only three pair markets are integrated, none of the other markets trading with Kinshasa and Lubumbashi respond in the short run to price shock in these reference markets. This weak linear relationship between markets can be postulated as one of major causes of food insecurity in the country.

Long-term effects of land-use on soil properties in the Ethiopian highlands

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The study was conducted to determine long-term effects of five different land-uses on soil properties. The study sites are located 240 km south of Addis Ababa close to the Rift Valley eastern escarpment at 2100 m.a.s.l and the soils are Humic Haplustands developed in a homogenous volcanic ash deposit. The five studied land-uses were plantations of *Cupressus lusitanica* and *Eucalyptus saligna*, farmland managed by mechanized agriculture (MF), traditionally managed farmland (TF) and an adjacent natural forest (NF) which was used as a reference site. The plantations of *Cupressus* and *Eucalyptus* were established on land used for mechanized farming nearly 30 years ago. The study is based on soil sampling at two occasions with a time interval of 10 years which allows comparisons between land-uses and determination of changes over time for each land-use. The results showed that in the 0-20 cm soil layer, the amount of soil organic C (SOC) followed the order *Cupressus*>*Eucalyptus*>NF> TF>MF. For total N, the order was similar with the exception that Eucalyptus had slightly less N compared to NF. The C/N ratio increased in the order NF<MF<*Cupressus*<TF<*Eucalyptus*. Although the NF had high amounts of SOC and total N in the 0-10 cm layer, it had considerably less SOC in the 10-20 cm layer compared to the plantations. The TF and MF had similar amounts of SOC and total N but MF had the highest amount of available P reflecting the more intensive fertilizer application in the mechanized agriculture. The changes that have led to the considerable differences between the land-uses seem to be continuing. After 10 years, a statistically significant increase is observed for SOC and total N under *Cupressus* and *Eucalyptus* plantations in the 0-20 cm interval while both MF and TF show a declining tendency for SOC and total N.

Effect of inoculating cowpea plants with indigenous cowpea rhizobia strain TUT53b2vu on N2 fixation, yield and nutrient uptake

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Cowpea (*Vigna unguiculata*) is the most important grain legume that is grown by smallholder farmers in Botswana and other Southern African countries. Its importance stems from its many uses, for example, the fresh young leaves and pods are used as vegetables, while the seed used in many food preparations. Apart from its uses for human consumption, cowpea is used as a fodder crop in other parts of the world. In this study, two cowpea genotypes, namely Bechuana White and Black Eye were planted in a randomised complete block design at the Botswana College of Agriculture farm in Sebele, Gaborone in January 2012. An indigenous cowpea rhizobial strain TUT53b2vu, originally isolated from a Tswana cowpea landrace growing in Dikhutsaneng in Botswana, was used to inoculate the seed prior to planting. The experiment was two factorial with inoculation

as the main treatment and the two cowpea genotypes as sub-treatments, and it was replicated four times. Shoot and root dry matter, nodulation (nodule number and weight), N2 fixation, seed weight, total N and P, macronutrients and micronutrients were analysed using standard procedures. Inoculation had no effect on shoot dry matter. Interestingly, the root biomass of inoculated plants was 5.7 times higher than that of uninoculated plants. The root biomass of inoculated Black Eye plants was significantly higher than that of uninoculated ones. There were, however, no significant differences between root biomass of inoculated and uninoculated Bechuana White plants. Seed yield for inoculated plants (1050 kg ha^{-1}) was 3.8 times higher than uninoculated ones (273 $kg.ha^{-1}$). Black Eye exhibited a significantly higher seed yield of 977 kg ha^{-1} compared to Bechuana White which yielded 345 $kg.ha^{-1}$. In summary, inoculation with strain TUT53b2vu significantly increased the root biomass and the seed yield of Black Eye while it had no effect on Bechuana White.

Effects of arbuscular mycorrhizal fungi on Moroccan Picholine olive plantlets under water stress

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In Mediterranean regions, a long dry season with low water availability has a large impact on tissue hydratation and plant physiology. The symbiotic association of plants and arbuscular mycorrhizal fungi (AMF) is of relevant interest in these regions because mycorrhizal plants have an improved ability for water and nutrient uptake under water deficit conditions. The objective of the present work is to evaluate the contribution of AMF (*Glomus manihotis*, *G. fasciculatum* and *G. agregatum*) hyphae to water relations preservation in olive (*Olea europaea* L.) under water stress. Plantlets from rooted cuttings of olive cv. Moroccan Picholine were subjected to two watering regime 75% of field capacity and 25% of field capacity. After ten weeks, plant weight and height, root and shoot dry matter, leaf relative water content (RWC), stomatal conductance, leaf water potential (Ψw), percentage of symplastic water (θ_{symp}), osmotic potential at full turgor ($\Psi_{\pi}100$) and osmotic potential at turgor loss ($\Psi_{\pi}0$) and biochemical parameters were measured in mycorrhizal (AMF-plants) and non-mycorrhizal plants (Non-AMF). Results showed that mycorrhizal colonization induces an increase in growth parameters (shoot height, root length and number of leaves) and biomass production (shoots and roots dry weights) as well as in well watred (75% of field capacity) and water stressed (25% of field capacity) plants. Under severe water deficit (25% field capacity), mycorrhizal olive seedlings maintained their water use efficiency, their relative water content and their stomatal conductance at a higher level. Data obtained by performing pressure-volume curves showed that symplastic water fraction, water potential, osmotic potential at full turgor and osmotic potential at turgor loss point were higher in AMF-plants than in non-AMF plants regardless of water status. The positive effects of AMF inoculation were more spectacular in seedlings inoculated with *Glomus manihotis*. Biochemical analysis emphasized the role of AMF in olive's water stress tolerance by increasing antioxidant enzymes activities and sugar accumulation.

Response of common bean to double inoculation with arbuscular mycorrhizal fungi and rhizobia

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An experiment was conducted in two varieties of common bean (*Phaseolus vulgaris*) 115 and Concessa to study the influence of the interaction between the arbuscular mycorrhizal fungi (AMF) *Glomus mosseae* (Gm) and *Glomus intraradices* (Gi) and the Rizobial bacteria R11 and R15 on arbuscular mycorrhizal root colonization and growth and biomass production in potted culture under greenhouse conditions. Overall, results showed that the mycorrhization frequency (> 60%) and the intensity of AMF root colonization (> 20%) were higher in Concessa than in 115. Biomass production (shoot and root dry weights) were higher in mycorrhizal (AMF-plants) than in non inoculated (non-AM) seedlings. The highest biomass production and plant growth was measured in seedlings colonized by *Glomus intraradices*. Moreover common bean plantlets associated with *Glomus intraradices* showed the highest mycorrhizal dependency values. Co-inoculation with rhizobia and AMF strains reduces the frequency of mycorrhization over 30% and the intensity of AMF root colonization more than 60%. Co-inoculation with Gi-R11 gives the highest shoot and root dry matter production in Concessa, while in 155 double inoculation gives low biomass production in shoot and root than that recorded when inoculating with AMF alone. Double inoculation reduced also nodulation and root phosphorus content. Nitrate reductase activity in nodules was higher in plants co-inoculated with Gi and R15 in both varieties, while foliar nitrate reductase activity was increased in both bean varieties.

Quality of cover crops in no-till systems influences soil biological function

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Small-scale farmers do not have sufficient means to improve the fertility of their soils. The no-till system under permanent cover crops (NT) is one of the practices that improve soil structure. This conservation agriculture is a considerable source of exogenous organic matters (EOM) through residue restitution and cover crops, essential for the bioavailability of nutrients. Many studies showed that the quality of the EOM (composition in N, soluble fraction, cellulose, lignin, and polyphenols) is a main factor for the decomposition and the mineralization or the immobilization of nitrogen. However, very few studies concerned with the effects of the EOM quality on soil biological compartment, the main component of soil functioning. Failure to consider the quality of cover crops in NT systems could lead to weak performance of the system. The objective of this communication is to show the interrelationships between the EOM quality from residues and living mulch (shoots and roots),

and the soil macrofauna as well as the microbial biomass and its enzymatic activities. A Principal Component Analysis was used for data analyses. Studies on no-till with permanent soil cover in the Highlands of Madagascar, considered different experimental treatments: i) annual crop rotation of corn-soybean on residue mulch; ii) annual crop rotation of bean-soybean on living mulch of *Pennisetum clandestinum* + crop residues; iii) corn without rotation on living mulch of *Desmodium uncinatum* + residues of corn; iv) annual rotation of rice-soybean on residue mulch. The results showed that the biomass and biochemical composition of the cover plants are of major importance to affect soil organisms. The abundance of macrofauna predators (Chilopoda, spiders, and adult coleopterans) was positively influenced by cover crop biomass (shoot and root) as well as by plant composition like polyphenols, soluble fraction and nitrogen content of plant shoot. This situation was met with the NT cropping system corn on *D. uncinatum* living mulch. It had the highest plant biomass and *D. uncinatum* had the highest polyphenol content. Microbial biomass, the heterotrophic respiration and the beta-glucosidase activity were positively correlated to the root content in soluble fraction and lignin and to the shoot content in cellulose. These plant compositions were met within the NT systems corn-soybean and rice-soybean on crop residues mulch. Microbial biomass was inhibited by plants' content in polyphenols. White grubs density and adult coleopterans biomass were positively influenced by plant hemicelluloses and soil mineral nitrogen (NO_3 and NH_4) content. The bean-soybean crop rotation with *P. clandestinum* had the highest NO_3 and shoot hemicellulose contents. The choice of plant and cover crops are important to regulate macrofauna and microflora biomass and activities. In the future, more no-till systems with multiple use cover crops for small-scale farmers will be analyzed.

Shared ectomycorrhizal symbionts between *Uapaca bojeri* and *Sarcolaena oblongifolia* facilitate their establishment in Madagascar

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Seedling establishment may be both inhibited and facilitated by pre-established plants. In the Madagascarian highlands, a large part of natural forest was replaced by shrub formations which in most case are well-known by their role on restoration processes of degraded soil and by their positive influence on plant regeneration. This study aims to determine the below-ground structure of ectomycorrhizal fungi community associated with *Uapaca bojeri* a native tree species and *Sarcolaena oblongifolia* a native shrub species in highland sclerophyllous forest of Madagascar and to assess the impact of shared ectomycorrhizal symbionts on tree seedling recruitment and plant succession facilitation. Ectomycorrhizal (ECM) fungi were identified based on morphotyping and RFLP analysis of rDNA internal transcribed spacer (ITS)-large subunit followed by sequence analysis of each RFLP pattern. Impacts of shared ectomycorrhizal symbionts on seedling development of *U. bojeri* were investigated in soil microcosms collected at different distances from naturally established of both shared ectomycorrhizal symbiont host plant species. The ECM fungal communities associated with both plant species showed high similarity and were dominated by the genus *Russula*. Expressed as RFLP types, 21 taxa of ECM fungi were collected from root tips. More than half of these ECM taxa were shared between the two plant species. Better development of *U. bojeri* seedlings was observed in soil samples naturally influenced by *S. oblongifolia* and located between 5 to 10 m from established *U. bojeri* where seedlings were colonized particularly by shared ectomycorrhizal symbionts. This study demonstrates that natural establishment of secondary colonizing hosts may contribute to tree seedling recruitment and development by providing compatible ectomycorrhizal symbionts.

La fertilisation du sol avec des poudres d'algues est améliorée par l'inoculation endomycorhizienne: cas du développement de plante de tomate

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Suite à la dégradation des sols cultivables par la forte pression anthropique, le rendement de culture dans les pays tropicaux en développement diminue considérablement. De ce fait, pour augmenter la rentabilité de l'agriculture, la fertilisation ou l'amendement du sol de culture est de règle.L'objectif de notre travail est d'améliorer la fertilisation des sols tropicaux tout en respectant l'environnement. En effet, dans ce travail, l'utilisation des algues marines comme fertilisants biologiques est couplée avec l'inoculation endomycorhizienne pour le sol de culture de tomate *Lycopercusum esculentum*.Différents traitements sont appliqués sur les sols de culture de *L. esculentum*: inoculation avec de la souche de *Glomus intraradices*, application de poudre de deux espèces d'algues marines *Gelidium sp*. et *Sargasum sp.* sur le sol et la combinaison des deux traitements (poudre d'algues et *G. intraradices*).Après 6 semaines de culture, les microorganismes rhizosphériques fonctionnels (actinomycètes, *Pseudomonas fluorescents*, bactéries à activité pectinolytique, bactéries à activité lipolytique) sont dénombrés et la biomasse aérienne et la croissance en hauteur des plantes sont évaluées.Les résultats ont montré que: (i) la biomasse et la croissance en hauteur des plantes de L. esculentum; ont augmenté significativement dans le cas de l'inoculation avec *Glomus intraradices* ainsi que par la combinaison de *Glomus intraradices* et chacune des deux poudres d'algue, (ii) les Colonies Formant Unités (CFU) des microorganismes rhizosphériques fonctionnels ont augmenté significativement avec la combinaison de *G. intraradices* et poudre d'algue.Ainsi, l'inoculation du sol de culture avec la souche fongique endomycorhizienne améliore la disponibilité des éléments nutritifs assimilables par la plante, par le biais de la stimulation des microorganismes fonctionnels du sol.

Sustainable intensification of farming systems through legume technologies: Lessons learnt for expansion of N2Africa to new countries

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N2Africa aims to expand the area cropped with grain legumes and improve the productivity of smallholder farms. The large scale of the project, initially in eight African countries, provides excellent research opportunities for cross-comparative analyses across countries, agro-ecologies and types of farmers. N2Africa is therefore framed as a 'development to research' project, with research analysing the experiences in dissemination and results from research feeding back into development activities. This feedback mechanism has helped to refine the project's approach as the N2Africa project is expanding into an additional five countries. First, there is a shift in focus from 'proof of concept' to 'understanding variability'. N2Africa started from the hypothesis that biological nitrogen fixation (BNF) and crop yields are determined by interactions of legume genotype (G_L), rhizobium strain (G_R), environment (E) and agronomic management (M): $(G_L \times G_R) \times E \times M$. Agronomy trials have proven this to be a valuable concept. However, understanding variability in BNF and yield remained a challenge. As part of the dissemination activities, farmers are carrying out simple, non-replicated trials on their own fields, testing the technologies offered to them. Monitoring these trials (300 farmers per country per season), supported by soil, climate and farm characteristics, can help explain the variability in responses as related to farmers' environment and management. In a next phase of N2Africa, these simple trials will be the focus for agronomic analyses. Classic agronomy trials will remain important to test emerging topics (e.g. soybean rust, intercropping arrangements, limiting nutrients other than N and P). A second lesson is the need for targeting technologies per farm type. Poor farmers tend to adopt technologies only if there is a direct increased return per unit land or labour. In monocultures, grain legumes often cannot compete with staple crops such as maize, millet or cassava in terms of land and labour use efficiency. However, grain legumes provide opportunities for relay or intercropping with main staple crops, thereby enhancing the returns to land or labour, also for the poorest farmers. For more commercial farmers, the profitability and financial risks of legume cultivation relative to other commercial crops are main determinants of the adoption of legume technologies. In the current project, baseline characterisations, modelling studies and adoption surveys led to ex-ante impact assessments, providing information on which farm types can benefit from which legume technologies. As N2Africa expands into new countries, more emphasis is placed on targeting technologies to different farm types from the start of the dissemination activities. Thirdly, N2Africa started with a Lead Farmer approach in all eight countries. However, experience suggests that a uniform approach in dissemination is not appropriate given the wide variety of methods already used by development partners and the different socio-economic and institutional environments. As the project expands, greater flexibility in dissemination approaches is envisaged while uniformity of data collection is required to facilitate cross-comparative analyses.

Indigenous arbuscular mycorrhizal fungi improve field establishment of tissue cultured AAA-EA and AAB bananas in Rwanda

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Tissue cultured (TC) bananas face challenges at establishment. Arbuscular mycorrhizal fungi (AMF) enhance nutrient uptake, have the ability to suppress pests and disease and can therefore be used to alleviate soil and pests and disease related constraints. A field trial was established at two contrasting sites in one of the major banana and plantain growing countries, Rwanda to establish whether AMF would help in the establishment and subsequent yield of TC bananas in Rwanda. Two distinct banana cultivars, cooking variety Mpologoma (AAA-EA) and a dessert variety Kamaramasenge (AAB) both of economic importance to Rwanda were established at two sites and inoculated with three indigenous AMF inoculants composed of two mixed and one single AMF species isolated from soils of banana plantations in Rwanda. Inoculation with AMF significantly ($p<0.05$) improved growth and yield of TC bananas. This was more pronounced on mixed than single AMF inoculants, with effectiveness evident on AAA-EA than AAB, and in soils with 50-80 mg kg^{-1} than 15.3-21.9 mg kg^{-1}. There is potential in indigenous AMF for improving establishment of TC bananas.

Managing soil fertility and timing of agronomic operations for diverse cereal crops for enhanced food self-sufficiency under increasingly variable climate in Zimbabwe

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Agronomic management of diverse cereal crops that occupy different climatic, biophysical and socio-economic niches may play a complementary overlapping role in stabilizing household food in smallholder farming systems in the face of increased climate variability. Field experiments were conducted for three subsequent seasons in 2009 in Makoni and Hwedza districts, eastern Zimbabwe to evaluate establishment, yield and financial benefits of maize, sorghum and finger millet under improved management of time of planting and soil nutrients in varying rainfall patterns. Emergence and establishment of unfertilized sorghum and finger millet were <5%, against > 80% for the fertilised crops in the three seasons in both study sites. Grain yield of the three crop species were significantly higher under high nutrient application rates than lower rates particularly in a good rainfall season in 2009/10. However, on relatively poor soils in Hwedza, the grain yields were less than 3 t ha^{-1} for all crop

species. Crops planted early or during the normal planting window gave comparable yields that were significantly greater than yields of late planted crops. Marginal rates of return for maize production was >100% under high nutrient application rate and less than <30% for the low rate in the 2009/10 season in Makoni. For finger millet, the financial returns were vice-visa with >100% for the low nutrient application rate, against <30% for the high rate. On poor soils in Hwedza, the financial returns were <50% for all the three crop species regardless of nutrient application rate. Substantial delay in planting gave very poor yields and negative financial returns mostly for maize. Calculation of provision of energy indicated that maize production gave the highest energy while finger millet provided the highest content of calcium. Use of high nutrient application rates on more fertile soils is an important strategy for achieving maximum economic yield as well as increasing nutrient use efficiency in maize production. While use of low amount of nutrients was financially most attractive for the production of small grains particularly finger millet. This suggests that production of small grains can be a potential adaptation option for resource-constrained farmers. Resource endowed farmers can maximize maize production by use of high amount of nutrients. Soil nutrient management increased crop production of all crop species between early and normal planting windows. Thus, soil fertility management can be an entry point for restoring farmers confidence to revive production of small grains to sustain household food and improve on nutrition in a changing climate.

Combination of lime, organic matter and fertilisers foster productivity of the acidic soils in Southern Rwanda

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Southern Rwanda is dominated by extremely acidic (pH ≤ 4.7, Al= 4 meq/100g of soil) and washed soils (base saturation = 20%) under *Eragrostis vidaceaa* K Schumach. A series of field experiments were undertaken in farmers' fields for crop production. The study aimed at (1) identifying the best Integrated Soil Fertility Management technology to address low productivity of these soils and (2) demonstrating the benefit of lime. The treatments were Irish Potato, wheat, climbing beans and soybeans during 4 consecutive cropping seasons. The experiment layout consisted of a set of four treatments (control, lime + farmyard manure, lime + fertilisers and lime + farmyard manure + fertilisers), the mother experiment, and farmers were requested to choose one or more treatments to try on their own fields: baby trials. Findings show that with the binary combination, there were yields but still very low. With the ternary combination, yields were spectacular: 30-40 t/ha of Irish potato, 3-5 t/ha of wheat, 3-4 t/ha of beans and 2-3 t/ha of soybean. Lime is expected to raise pH, to supply Ca^{2}+ and Mg^{2+}, to avail P and to neutralise Al. Organic matter is expected to increase the CEC and the fertilisers to supply nutrients (NPK). It is concluded that to expect any food production in those soils, the combination of lime+organic matter+fertilisers is absolutely required. Furthermore, the mother and baby demonstration trials approach is efficient to create awareness and to speed up technology adoption.

Labour burden not crop productivity increased under no-till planting basins on smallholder farms in Murehwa, Zimbabwe

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No-till planting basins are promoted using seed and fertiliser inputs as incentives for their widespread uptake in Zimbabwe. No-till planting basins are planting holes measuring 15 cm width x 15 cm length x 18-20 depth, spaced 60 cm within the row and 75-90 cm between rows leaving up to 90% of the soil surface undisturbed. They are intended to conserve moisture and improve the targeting of nutrient application. We evaluated the effect of planting basins on crop yield and labour requirement in an on-farm experiment over two seasons in Murehwa district, Zimbabwe. The experiment was established in clay and sandy soils, in two fields types; degraded and better managed fields in 2009/2010 and 2010/2011 seasons. Two tillage treatments i.e mouldboard ploughing and no-till planting basins were tested. Tillage plots measured 1080 m^2 (18 m x 60 m) and labour hours were derived by direct measurement in these plots. Due to grazing in the dry season, soil surface cover by crop residues in the experimental fields was less than 10% in both seasons. Previous field management, nutrient management in the experiment and season had a significant effect on crop yields ($p < 0.001$); there was no significant effect of tillage. The largest maize grain yield of 5.6 t ha^{-1} was obtained with a combination of 3 t of manure and 60 kg N ha^{-1} under conventional tillage the equivalent treatment under planting basins yielded 4.6 t ha^{-1} in the 2009-2010 season. Rainfall was poorly distributed in 2010-2011 season and the same treatment gave the largest grain yield of 1.6 t ha^{-1} under conventional tillage and 1.2 t ha^{-1} under no-till planting basins. Land preparation under conventional tillage required 6 man days ha^{-1} while making planting basins required 27 man days' ha^{-1} for the clay soils and 15 man days ha^{-1} for the sand soils. Weeding in planting basins required 40% more labour compared with conventional tillage (12 man days ha^{-1}) due to greater weed densities associated with no-tillage. Planting basins did not enhance moisture conservation in a the 2010-2011 season when rainfall was poorly distributed. The increased labour requirement suggests it is unlikely that farmers will abandon the plough in favour of the hand hoe especially if they own cattle. Planting basins are easier to make in sandy soils and require less labour than in clay soils. Conversely, they are easier to maintain in clay soils than in sandy soils. Although planting basins were practiced by about 98% of farmers, the maximum land size allocated to planting basins was only 0.2 ha per farm, 10% of the landholding at most. Given that planting basins increase the labour burden but not crop yield, widespread adoption by smallholder farmers seems unlikely.

Effect of micro-dose fertilizer on nitrogen fixation of groundnut and cowpea in the Sahel

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The objectives of this study are to determine a micro-dose effect, using NPK as starter dose, on rhizobium populations around cowpea and groundnut rhizospheres and free living azotobacteria around sesame rhizospheres. This study will also help to determine the micro-dose on pure culture of these crops in the Sahel by assessing the biomass and grain yield. The study was conducted in three agro-ecological zones of Niger (at Bengou, Dosso; at Tarna, Maradi; and at Magaria, Zinder). The treatments include different levels of the fertilizer and two varieties (local and improved) of the three crops. The experimental design was Split plot with the different levels of NPK (15-15-15) on the main plots (20m x 4m) and the varieties on the sub plots (10m x 2m) with 4 repetitions. The different levels of NPK on sesame were 0, 1, 2, 3 and 4 g/hill (0-40 kg ha^{-1}). The different levels of NPK application on cowpea were 0, 1, 2 and 3 g/hill (0-30 kg ha^{-1}). The application rate on groundnut were 0, 0.5, 1, 1.5 and 2g/hill (0-20 kg NPK ha^{-1}). This paper presents the preliminary results of this study.

Effects of tillage, crop rotation, and nitrogen fertilization on maize and soybean under rain fed conditions

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Although tillage systems (conservation agriculture and conventional tillage) and crop management systems (continuous, intercropping and rotations) can affect crop production and uptake of nutrients, their long-term effects, particularly their interactions, are not well-documented. Therefore, a study was conducted to evaluate the influence tillage (no-till and conventional) and cropping (rotated, intercropped and continuous) systems on maize and soybean production under rainfed conditions over 8 years. We measured the yields of maize and soybean through two rotation cycles and intercropping system (maize and beans), of four crop rotations managed under conventional tillage (CT) and conservation agriculture (CA) systems. The study was conducted 2003 through 2010 on a Ferralsol soil in western Kenya. The two-course crop rotations were: (i) soybean-maize (ii) continuous maize (CW). The crops were fertilized using regional recommendations based on soil test results. Tillage practice and crop management system affected both maize and soybean yield. Grain yield during the long and short rains seasons was greater with rotation than both continuous and intercrop for both maize (2.84 t/ha, 2.31 t/ha and 1.40 t/ha) and soybean (0.634 t/ha vs 0.265 t/ha). The benefit of rotation in terms of grain yield was greatest for both maize and soybean under conventional tillage practice. There was interaction of tillage system with crop rotation on both maize and soybean yield. During the second rotation cycle, N fertilizer requirement decreased, and maize yield higher, under CT as compared to CA. This study showed that (i) field soybean is an attractive legume cover crop; and (ii) recommendations for N from soil test results should factor in the type of tillage and crop management system used.

Scaling-up Minjingu phosphate utilization for balanced fertilization of crops in Tanzania

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Demonstrations were conducted in 34 sites distributed over seven districts in three regions, namely Kilimanjaro, Morogoro and Tanga, to demonstrate the effects of different fertilizer combinations on maize and rice yield. The treatments used in the demonstrations were: (i) Farmers Practice (FP) in which no fertilizer was applied, (ii) nitrogen from urea at 60 kg N ha^{-1} (urea), (iii) phosphorus (P) from diammonium phosphate at 20 kg P ha^{-1} + urea at 60 kg N ha^{-1} (DAP), P from Minjingu Mazao at 20 kg P ha^{-1} + urea (Mazao) and P from Minjingu phosphate at 20 kg P ha^{-1} + urea (Minjingu). The results indicated that application of nitrogen increased yields of maize and rice significantly in all demonstrations and the increases in yields gave positive net returns. This confirmed the suspicion that N was a major yield limiting nutrient in the study area and that its application was economical. With regard to P fertilizers, DAP gave significantly higher yields than urea alone but the increase in yield did result in positive net returns. The effects of Mazao and Minjingu on overall mean yields were not significant. However examination of results on a district by district basis revealed cases where DAP and Mazao gave significant increases in yields and positive net returns. We therefore conclude that efforts to encourage N application should continue over the whole study area while for P application should be done more selectively.

The abundance and diversity of rhizobia in tree plantations of Bandia, Senegal

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Several fast-growing and multipurpose tree species have been widely used in West Africa to both reverse the tendency of land degradation and restore soil productivity. Although beneficial effects have been reported on soil stabilization, there still remains a lack of information about their impact on soil microorganisms. Our investigation has been carried out in exotic and native tree plantations of 28 years and aimed to survey and compare the abundance and genetic diversity of natural legume-nodulating

rhizobia (LNR). Soil samples were collected twice, during the wet and dry seasons of 2008 in a forest reserve at Bandia, Senegal. The study of LNR is supported by the phylogenetic analysis which clustered the isolates into three genera: *Bradyrhizobium*, *Mesorhizobium* and *Sinorhizobium*. The results showed close positive correlations between the sizes of LNR populations estimated both in the dry and rainy seasons and the presence of legume tree hosts. There were significant increases in *Rhizobium* spp. population densities in response to planting with *Acacia* spp., and high genetic diversities and richness of genotypes were fittest in these tree plantations. This suggests that enrichment of soil rhizobial populations is host-specific. The results indicated also that species of genera *Mesorhizobium* and *Sinorhizobium* were lacking in plantations of non-host species. By contrast, there was a widespread distribution of *Bradyrhizobium* spp. across the tree plantations, with no evident specialization in regard to plantation type, although the densities of their populations were positively influenced in the N_2 fixing tree plantations. Finally, the study provides information about the LNR communities associated with a range of old tree plantations and some aspects of their relationships to soil factors, which may facilitate the management of man-made forest systems that target ecosystem rehabilitation and preservation of soil biota.

Finding niches for drought tolerant, short-season lablabs in semi-arid farming systems of Eastern Africa

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*Lablab purpureus*is one of the most diverse domesticated legumes available and offers many opportunities to improve food and forage production in smallholder farming systems of semi-arid areas. Besides being better adapted to drought than cowpeas (*Vigna unguiculata*) and common beans (*Phaseolus vulgaris*) which are widely cultivated in semi-arid areas of the tropics, lablab is highly valued because of its multi-purpose uses that include protein rich grain, healthy vegetable leaf and pod products, high quality forage and green manure. The high agro-morphological and physiological diversity of lablab, and in particular the short season varieties, offer farmers additional options for coping with frequent droughts and reductions in rainfall, sustain soil fertility and stabilize on-farm production. But adequate characterization data, in particular for short-season lablab varieties, is largely missing and the genus *Lablab* should be considered a neglected crop. The focal point of the present study was to collect key agronomic information for potential short-season lablab varieties which can be processed in crop modeling software for agricultural system simulation, such as APSIM (Agricultural Production Systems sIMulator), to identify suitable candidates for mixed farming systems in semi-arid areas. Previous work from Southern Africa tested 33 lablab accessions selected from a collection held at the Australian Tropical Forage Genetic Resources Centre in Australia on the basis of relatively early flowering or appropriate grain types. Three field evaluations where conducted in Limpopo province of South Africa from 2002 to 2008 with measurements of emergence, biomass production, days to flowering, physiological maturity, seed and pod yield. Five accessions (CPI52552, CPI60795, CPI81364, CQ3620 and Q6990B) were found to be consistently early flowering (43 – 70 days after planting) and considerably productive (seed yield 331–1233 kg ha^{-1}). This study has been extended to further evaluate photoperiod sensitivity, productivity under drought stress and acceptability of these and other accessions from the ILRI collection under low latitude conditions at Machakos in Kenya. Crop models have also been parameterized to develop risk profiles and to explore adaptability and suitability across a range of environments particularly considering climate variability. Our strategy aims to provide new dual-purpose legume options to farmers in vulnerable areas of Eastern Africa.

Integrated Nutrient Management in Indo-Gangetic Plains improved total microbial activity of soil under a rice-wheat cropping system.

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The rice-wheat cropping system is the most important double cropping system in the northern Indo-Gangetic Plains (IGP) of India, but this highly productive system is facing the problem of yield stagnation along with increase in environmental pollution due to increased use of chemical fertilizers and irrigation. To meet the challenge of increasing productivity and curbing environmental pollution by reducing dependence on energy intensive processes, resource management practices are being extensively explored. The aim of this study is to evaluate effects of improved resource management practices of tillage, irrigation and nutrients on total microbial activity and fertility of soil during rice-wheat cropping system in IGP region of northern India. Using standard procedures, we measured the total microbial activity (i.e. Ferredoxin diacetate hydrolysis) during conservation and conventional tillage with 2-, 3- and 5-irrigations (each at the gap of 20 days) and various combinations of chemical and organic fertilizers for two rotation years (i.e. 2006-07 and 2007-08). A significantly higher FDHA activity (222.41% to 397.81%) was measured in conservation (zero) tillage wheat fields over that in the conventional tillage plots. The use of conservation tillage with optimum irrigation have reduced the use of chemical fertilizer at least by 25%; increased the rice and wheat yield by 4% and 18%, respectively and significantly ($p<0.05$) increased the total microbial activity in rhizosphere soil of rice and wheat crops. The use of organic sources (i.e. where 25% or complete replacement of urea with organic sources have been made) have significantly ($p<0.05$) increased the soil microbial activity as well as yield parameters as compared to the treatment where no external nitrogen source was used (i.e. control) or where a completely chemical N-source (i.e. RDN as urea) was used. As compared to conventional tillage or irrigation practices with high application rates of nitrogenous fertilizers, the conservation practices presented here have obviously positive environmental effects along with increase in grain yield and beneficial soil microbes.

Using the Rasch Model to explain farmers' behaviour towards adoption of soil fertility management technologies in Kenya

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Studies conducted to measure perception and attitudes have relied on use of factor analysis (Likert scale) premised on the theory of planned behavior. Recent studies have, however, argued that the theory of planned behavior (TPB) has major limitations. Specifically, these studies argue that TPB narrowly focus only on how people's attitudes affect their behavior. This study uses the Rasch model, which is based on the items response theory and finds that there exists a discrepancy between self-reports in evaluative statements and actual behavior. It then empirically identifies areas where the theory of planned behaviour is inadequate.The study uses data collected from 185 farmers comprising 155 and 30 vegetable and flower growers, respectively. The data was collected through personal interviews using pre-tested questionnaires.The results of factor analysis show that the most important factor in explaining farmers' perception of soil fertility management is the hiring of labour to apply livestock, compost, and farmyard manure, followed by biomass transfer. Other important factors include farmers' training, method of harvesting cow dung and urine, farmers' endowment of social capital, and cost of obtaining livestock manure. The Rasch model shows that it is relatively easy for farmers to practice crop rotation and intercropping as well as incorporating livestock manure into the soil. Use of agro-industrial by-products was found to be the most difficult task. It is also difficult for farmers, particularly in Kibera, to mobilize their neighbours to assist in applying manure. Moreover, making arrangements with neighbours for manure supply, as well as collecting crop residues from the neighbours is also difficult to farmers. The study therefore finds that there exists a discrepancy between what farmers perceive to be of importance to them and what is actually practiced in terms of sustainable soil fertility management. Based on the findings, this study concludes that the Theory of Planned Behaviour is not adequate in explaining human behaviour relating to integrated soil fertility management because it does not take into account the level of difficulty of undertaking the different practices involved. The study recommends that research aiming at understanding the adoption behaviour of farmers, particularly towards emerging technologies, should use the Rasch model in order to explicitly explain why farmers choose some practices over others. This is important in terms of policy in order to promote use of the most frequently used technologies while reducing the risks perceived to be associated with those practices that are rarely undertaken.

Soil characterization in contrasting cropping systems under the fast track land reform programme in Zimbabwe

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Soil fertility depletion is a major limitation to crop production in Sub-Saharan Africa and Zimbabwe is no exception to this phenomena. This research was embarked upon so as to assess the soil chemical characterization in three contrasting cropping systems of Zimbabwe. The contrasting production systems under study were communal area, A2 (large-scale resettlement) and A1 (small-scale resettlement). All these systems are in Manicaland province, Zimbabwe. The A1 and A2 production systems were brought about during the 2000 land reform programme. The soil samples where collected during the off season of 2006, 2007 and 2008. The following soil chemical characteristics were determined; Ca, Mg, K, Zn, pH and organic matter. There were significant differences (P=0.001) between the production systems and soil chemical properties. Calcium, Magnesium and Potassium levels were generally low in all the three production systems. This was due to low soil pH. However, A2 farms had significantly the highest (P<0.05) Ca, Mg and K and communal area had significantly the lowest (P<0.05) soil organic matter. The soil organic matter content in A2 farms can sustain plant growth without the addition of any organic material. However there may be need for the communal and A1 farmers to apply organic matter so as to boost SOM in their fields. The optimum soil organic matter in Zimbabwe is from 1.5% to 5%. Results showed that soil pH was between 5.0 and 6.8 (generally acidic), in all the three production systems. However it was strongly acidic in communal areas at 0-30 cm depth. Soil acidity in communal areas impacted negatively on the yield of maize and groundnut. In the A1 and A2 farms, acidity levels may sustain the production of crops like tobacco and sunflowers. There is need for the farmers in the three production systems to lime the soils and improve their organic matter through addition of crop residues and cattle manure.

Effect of varying crop planting density in a soybean-maize intercrop in Western Kenya

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A study to assess the effect of varying soybean planting densities on yields of both soybean and maize and subsequent maize in maize: soybean intercrop was conducted in Butere and Mumias districts of Western Kenya during the short and long rain seasons of 2011 and 2012, respectively. Field experiments involving three planting densities of maize:soybean; 1:1, 1:2 and 1:3 was conducted. Three soybean varieties NAMSOY, SC SQUIRE and TGx1987-18F were tested in a randomized complete block design replicated three times during the first season and in the second season maize was planted as sole crop on the same plots. Soybean biomass and yields of both maize and soybean as well the associated production costs were determined. High biomass was obtained in the 1:3 maize:soybean planting density with TGx1987-18F registering the highest (4093 kg/ha). Whereas for soybean grain yields, the maize: soybean density 1:2 had the highest (1297 kg/ha). For maize yields there were no significant

differences in density 1:1 (1596 kg/ha) and 1:2 (1628 kg/ha). For better land utilization and optimization of yields, intercropping maize:soybean at a planting density of 1:2 is recommended for one season cropping however, since intercropping benefits are usually pronounced in the succeeding season, the 1:3 planting density could prove better over the longer-term.

Effect of tied-ridging and enhanced soil fertility on maize yields in semi-arid Kenya

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The major constraint to maize production in Arid and Semi Arid Land (ASAL) areas of north Rift Kenya is low soil moisture due to low and erratic rainfall patterns, coupled with inherent low soil fertility. Despite this major constraint, maize cultivation is practiced by farmers, often with poor or no yields at all. Tied ridge water harvesting technology for run–off collection and utilization has been found to tremendously increase crop yields in ASAL areas where the production would otherwise be nil or extremely low. An on-farm evaluation of tied-ridging water harvesting and enhanced soil fertility on maize production was carried out in Mogotio district. The objective was to determine the best combination of farmyard manure (FYM) and fertilizer application rates, and water harvesting techniques in maize production. The on-farm trial was a factorial laid out in a randomized complete block design with tied ridges and flat planting as the water–harvesting treatments while farmyard manure (FYM) and fertilizer application rates formed the fertility treatments. The trial was replicated 4 times. The trial comprised 10 treatment combinations. The Treatments and their combinations were as follows: W1 – Tied ridging water harvesting technique. W2 – Conventional water harvesting technique (flat planting). T1 - 130 kg/ha DAP and 150 kg/ha CAN T2 - 130 kg/ha DAP only T3 - FYM at 4 tonnes/ha and 150 kg/ha CAN T4 - 4 tons/ha FYM only T5 - 0 FYM, 0 DAP and 0 CAN-(control) The Treatment combinations were: W1T1, W1T2, W1T3, W1T4, W1T5, W2T1, W2T2, W2T3, W2T4, and W2T5. Plot sizes of 4m x 3m, were used. A spacing of 90 cm x 30 cm was adopted. Each plot had 5 rows of which the middle three rows were harvested for data collection and analysis. Plots under tied ridges were tied at 2 m intervals. There were no significant differences between the recommended full rate basal application of DAP, at 130 kg/ha, and full rate top dressing application of 150 kg/ha of CAN, with that of DAP application only, at the basal rate of 130 kg/ha, without any subsequent top dressing, for both the tied-ridged, water-harvesting plots as well as the flat planting (conventional) plots. Similarly, there were no significant differences between the manure application coupled with full rate top dressing application of 150 kg/ha of CAN, with that of manure application only, without any subsequent top dressing, for both the water-harvesting plots as well as the flat planting (conventional) plots.

Effect of eucalyptus amendment on soil chemical proprieties, enzymatic activity, acacia plant growth and root symbiosis

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The aim of this study were to test the effect of *Eucalyptus camaldulensis* litter on growth, roots colonization, roots nodulation and nutrition of Sahelian Acacias (*A. senegal*, *A. seyal*, *A. albida*). Experiments were made in PVC tubes, with a sandy soil amended with eucalyptus litter at two doses 1 and 5% (w of litter/w of soil). In order to compensate litter addition, control treatments were amended with *Zea mays* litter to respective dose 1 and 5%. In addition, a control without amendment was established to highlight the changes caused by these amendments. Eucalyptus litter impact on each Acacia was determined by comparing plants grown in treatments amended to plants grown in control treatments. Results indicated that eucalyptus litter lead to changes in soil chemical characteristics especially in phenol content and pH (decrease pH and increase phenol). Such changes negatively affect plant growth (shoots and roots dry matter weight), their symbiotic status (mycorrhization and nodulation), and their nutrition (leaves chlorophyll content, total C, total N and P in shoots). Effects were significant at 5% from eucalyptus amendment. Likewise, soil enzymatic activities, were modified. Higher acid phosphatase were recorded in soil amended with eucalyptus litter while alkalin phosphatase were higher under controls treatments. In most of the cases, our results show positive correlation between these root symbioses and shoot mineral content (C, N and P) suggesting that AMF and N-fixing symbiosis promote C, N, and P uptake. However polyphenol contents were negatively linked to root symbiotic and growth variables regardless the *Acacia* species.

Effect of arbuscular mycorrhiza and plant growth promoting rhizobacteria on wheat–rice and wheat–vigna cropping systems

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Arbuscular mycorrhizal fungi (AMF) and plant growth promoting rhizobacteria (PGPR) have been promoted for a long time as "bio-fertilizers" for various crops. However, knowledge about their effects at the field level is still at its infancy. Here, we present the work carried out under the umbrella of the "Indo-Swiss Collaboration in Biotechnology", in which AMF and PGPR were evaluated at realistic field conditions in two different cropping systems prevalent in the Indo-Gangetic plain: wheat – rice and wheat–vigna. Our results demonstrate their efficacy, and they pave the way for their commercialization. The "biofertilizer" inoculants used in our field experiments were initially isolated from roots of wheat growing in the marginal land located near District Budaun, Uttar Pradesh, India. AMF inoculation was performed with a natural consortium (Mnat) multiplied via host plants. In addition, two AMF single strains multiplied via a root organ culture were applied (an AMF strain isolated from Mnat

and a commercial strain). The PGPR inoculum consisted of two fluorescent *Pseudomonas* strains, namely *P. jessenii* (R62) and *P. synxantha* (R81). The PGPR inocula were multiplied in a fermentor by a special process. The field experiments were performed as mid-term trials (2005 – 2009), comparison trials (2008 to 2010), and validation and demonstration trials (2009 – 2011). We found that dual inoculation of wheat seeds with PGPR and AMF before planting increased subsequent grain yield by 41% in mid-term and 21% in comparison trials, compared to un-inoculated controls. Yield responses to the inoculants were highest at locations with previously low yields. The bio-inoculants were effective both in the absence of fertilization and at farmers' practice fertilization level (70 kg N ha^{-1}, 11 kg P ha^{-1} in mineral form to wheat crop). Also, the concentration of raw protein and mineral nutrients (P, K, Cu, Fe, Zn, Mg) in the harvested grains were higher after inoculation (+6% to +53%) in both mid-term and comparison trials. In particular, P use efficiency of wheat grains [kg P grain kg^{-1} P fertilizer] was increased by 95%. AMF and PGPR application also improved soil quality, as indicated by increased soil enzyme activities of alkaline and acid phosphatase, urease and dehydrogenase. We performed twelve validation and demonstration trials in the principal areas of wheat cultivation in India, covering six states of North India. We found that AMF and PGPR application resulted in an overall enhancement of around 12% in wheat grain yield. In summary, the results of our field experiments demonstrate that AMF and PGPR biofertilizers have a great potential to promote yield and quality of wheat crops in India, more under marginal conditions but also under fertilized conditions, and that they may be a commercially valid alternative to conventional fertilization.

Meta-analysis of fertilizer use response across maize production systems in sub-Saharan smallholder landscape

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Fertilizer recommendations currently designed in sub-Sahara (SSA) rarely consider standardized soil-testing procedures, spatial variation and smallholder farmers' local conditions. Values form soil tests can be interpreted in terms of nutrient availability for crop requirement. Although site-specific soil, clay and carbon content influence the relation between soil nutrient content and fertilizer effectiveness, most of these factors are not quantitatively considered when assessing fertilizer use recommendation. In this study, results from experiments conducted during the past three decades in SSA were analysed using meta-analysis technique. Soil nutrient content, fertilizer-application treatments, nutrient-use efficiency, and soil test attribute values for potassium (K) and phosphorus (P), increased maize yield responses compared to the control. The results may be used in a novel approach to predict the probability of maize yield increase for a specified combination of fertilizer-application and site-specific data.

Allanblackia: a tree crop undergoing domestication: What are the soil requirements and important symbionts?

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In order to improve livelihoods and enhance food security and resilience of rural communities, diverse and multifunctional agricultural systems are promoted. There has long been a lack of investment in domestication of plant species that are specifically suited to African farmers' circumstances, but there is now a growing demand for commercialization and use of local crops and trees. One example is the indigenous tree *Allanblackia* which seeds contain high-value edible oil. Traditionally, *Allanblackia* seeds have been collected from wild stands by rural communities, but more recently access to wild stands is threatened by deforestation. During the last decade, *Allanblackia* oil has further received attention from industry as raw material in the production of spreads and soaps, increasing the demand for Allanblackia seeds. In response to this ICRAF in 2002 launched a research program aiming for the domestication of *Allanblackia* tree species on smallholder farms. Up to now, research activities have focused on selection of highly productive plant materials and propagation methods. However, to fully optimize the harvest potential of domesticated *Allanblackia*, the trees´ requirements for nutrients and water must be met, but knowledge on this is largely lacking. Work carried out on management of *Allanblackia* seedlings at the nursery has preliminarily shown that incorporation of soil collected from native *Allanblackia* stands in the potting medium enhances growth of seedlings, indicating a positive plant-microbial interaction. Symbiotic relationships between plants and micro-organisms are very common and often stimulate nutrient and water uptake from the soil. However, in this case it remains to clarify if such interaction exists and, if so, which organisms are involved and how they can be promoted in the nursery and on farm-land. The purpose of this study is to obtain information about the environmental requirements of *Allanblackia* and it has two main objectives. The general soil chemical and physical parameters of natural *A. stuhlmannii* stands will be determined and will with information on climatic conditions and the soil water regime be used to characterise the abiotic requirements of the species. Biological enhancing factors will be sought, with a particular focus on mycorrhizal symbionts. The fieldwork will be carried out during August-September 2012, in the Eastern Arc Mountains, Tanzania. Together with local expertise and researchers at ICRAF, native *Allanblackia* stands will be localised and site characteristics, such as elevation, slope and drainage assessed. In addition, soil samples will be collected for characterisation of chemical and physical properties, such as soil pH, major plant nutrients, soil organic carbon, soil texture, bulk density and water holding capacity. The root systems will also be traced from the tree and root fragments collected, bleached and stained. These will subsequently be examined for occurrence of arbuscules and vesicles in the search for possible symbionts, and degree of colonisation determined. The study will provide knowledge on the environmental requirements and biological relationships essential for understanding the tree's biology and appropriate cultivation practices and thus contribute to the domestication process. Preliminary results will be presented at the conference.

Relative growth rate and its components for East African highland banana as affected by water, potassium and nitrogen supply in Uganda

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Drought stress, potassium (K) and nitrogen (N) deficiencies constrain East African Highland banana (EAHB) production in Uganda. Understanding EAHB coping mechanisms against these stresses is necessary for designing management practices suitable for smallholder farmers. This study evaluated the relative importance of physiological (Net Assimilation Rate or NAR) and morphological (Leaf Area Ratio or LAR) components of Relative Growth Rate (RGR) in driving EAHB growth rate as affected by water, K and N supply in Uganda. Plants from 2 Nutrient Omission Trials grouped into 'Control' (no nutrient inputs), 'Sole N', 'Sole K' and 'K+N', were surveyed. Plants in each group were subdivided into 'Wet' and 'Dry', if their cumulative rainfall 365 days from emergence (CRF_{365}) was ≥ and <1100 mm, respectively. Plant height and girth at base data were used to estimate leaf area (LA), leaf dry matter (LDM) and total dry matter (TDM) per plant at monthly intervals between 6 and 3 months pre-flowering via allometry. RGR and its components were computed using the classical approach to growth analysis. Analysis of variance was used to evaluate CRF_{365}, K and N effects on LA, LDM, and TDM. Natural logarithm-transformed (ln) NAR and LAR were separately regressed on ln RGR to evaluate their relative importance in sustaining crop growth rate. LA, LDM and TDM significantly increased with K ($P<0.001$) input and 'Wet' ($P<0.05$) conditions. RGR was more strongly driven by its physiological or NAR (slope = 0.895; R^2 = 76.0%) than morphological (LAR) component. Adequate K supply was critical for the EAHB to exploit NAR for sustaining crop growth rate. Under limiting K supply, EAHB mitigated reduction in crop growth rate morphologically through increased specific leaf area provided 'Wet' conditions prevailed. Smallholder farmers can therefore sustain rain-fed EAHB production with K-rich mulches or modest mineral K inputs.

Does the inclusion of legumes in cereal cropping systems result in a positive nitrogen balance?

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A greenhouse study was conducted to estimate nitrogen (N) budgets, quantify biomass productivity and nitrogen fixation by cowpea grown as sole and intercropping with sorghum on Seibersdorf, Waldviertel and Krumbach soils from Austria. The ^{15}N isotope dilution method was used to quantify biological nitrogen fixation while a simple input/output model was used for budgeting. At 90 days after sowing, sole cowpea biomass attained 0.35 g m^{-2} to 0.64 g m^{-2} with no yield reduction following intercropping while cowpea derived 16% to 47% N from fixation. At 120 days, intercropping resulted in reduction of cowpea biomass by 45-53% and sorghum biomass by 28-58% while also reducing the amount of N fixed on Seibersdorf. Sole cowpea on Seibersdorf derived the highest N ~60% from fixation while on Krumbach derived 43%. Overall, cowpea derived 10-60% N from fixation. Incorporating biomass gave a positive N balance with sole cowpea having higher +1.93 balance than intercropped cowpea +0.53. Exporting biomass gave negative N balances, except for sole cowpea grown on Seibersdorf and Krumback. It was shown that inclusion of legumes in cereal cropping systems results in a positive N balance if the legume effectively fix large amount of nitrogen and is incorporated into the soil.

Wetland utilisation, agricultural production and marketing in the Ewaso Ngiro Basin, Kenya

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Land use changes in Upper Ewaso Ngiro basin have undergone significant transformation in the past 100 years, from nomadic communal grazing land before 1900, large scale ranching up to early 1970s to small-scale farming from the 1990s. The later change has been accompanied by increased food crop and horticultural cultivation that is geared towards both domestic and commercial needs by migratory agrarian communities from more humid regions. Due to the arid nature of the basin, cultivation mainly involves irrigation of drylands or farming in the several wetlands in the basin upon draining. Lack of clear legal framework has resulted in severe degradation of wetlands ecosystem with wetland area reduced by about 80%. Although the wetlands ecosystem renew themselves annually during the long rains through excessive flooding, regaining exploited soil fertility, the cumulative impact of anthropogenic effect is reflected mainly in vegetation change. Again, since the land tenure in the wetland is insecure, this also means that there are minimal conservation efforts in place to facilitate soil and nutrient conservation measures. The land is perceived to be free and has been allocated in small sizes (0.5 to 1 acre) for farming. Horticultural farming and marketing is characterised by high dominance by brokers, who limit farmers access to the market, where farmers in spite of accessing financial credit are poorly organised to break through the brokers' chain. Farming is characterised by recurrent loses, food crop and finances due to a combination of low farming inputs and poor market access, which further limit resources input for land and soil management. This results in sustained low food production and continued agricultural resource degradation.

Improving nodulation and biological nitrogen fixation of promiscuous soybean through inoculation with commercial rhizobia inoculants

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Nitrogen (N) is a major limiting factor in plant growth and development in Sub-Saharan Africa is one of the major constraints among others to soybean production. Soybean is a specific nodulating and is only capable of establishing a symbiotic partnership and the process of biological N_2 fixation (BNF) with mainly strains of *Bradyrhizobium japonicum* and*B. elkanii*, and can fix up to 80% of its N needs. The International Institute for Tropical Agriculture (IITA) breed promiscuous soybean varieties designated TGx varieties capable of nodulating with indigenous rhizobia. Low effectiveness of indigenous strains has widely been reported and nitrogen fixation and grain yields have remained low. Commercial inoculants and strains were obtained and tested through screening in the greenhouse and field. Selected inoculants were then subjected to further testing in 38 farms across Bungoma and Meru south districts. The objectives were (i) to identify inoculants and strains with potential for use as commercial inoculants for promiscuous soybean, (ii) to test the competitiveness of commercial inoculants in soils with low and high levels of indigenous strains capable of nodulating soybean, (iii) to test the persistence and adaptability of the commercial strains in our Kenyan soils and (iv) to understand the differences and similarities in nodulation, nitrogen fixation and biomass yield exhibited by major soybean inoculant strains. Nyala (non-promiscuous), TGx1740-2F and TGx1835-10E (promiscuous) were the soybean varieties used. There were significant increases in levels of nodulation, nodule occupancy, biomass yield, grain yield and biological nitrogen fixation both at the greenhouse and field. Field trials were on two site with data from Siaya site which is used as a soybean multiplication site showing the commercial inoculants with 5 % nodule occupancy and an indigenous strain identified as *B. elkanii* (after isolation) occupying most nodules. At the Meru south site with no soybean growing history nodule occupancy was dependent on the inoculant with Legumefix and 1495MAR showing 100% occupancy. On the 2nd season where no inoculation was done, Legumefix showed better persistence with 75% nodule occupancy while 1495MAR had 50% occupancy. Rainfall was an important factor that influenced both nodulation and grain yields especially during the 1st season (long rains 2009). In the multi- site trials Legumefix, Histick and Rizoliq Top showed high consistency in nodulation and nodule occupancy in the farms tested. This showed that commercial strains can be used to inoculate promiscuous soybean varieties. Molecular tests on major commercial bradyrhizobia strains showed they fall into two major groups by the 16S rRNA gene through polymerase chain reaction- restriction fragment length polymorphism (PCR-RFLP) and phylogenetic tree. However by use of monoclonal antibodies more differences exists between the strains and this was shown by their differences in BNF on both Nyala and TGx1740-2F. It was concluded that commercial inoculants would beneficial to use as inoculants on soybean and their persistence in the soil may depend on the variety used.

Inoculation of legumes and its outcome on soil bacterial dynamics in potato cropping systems

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Symbiotic nitrogen fixation can act as a renewable and environmentally sustainable source of nitrogen and can complement or replace fertilizer inputs. Inoculation of legumes has been widely used to improve legume productivity in fields. The benefits of inoculation may also be mediated to non-legume crops grown in rotation by increasing yields and reducing disease infestation. However, little is known about the indirect effect of legume inoculation on soil bacterial communities. In this study, the impact of inoculation of *Phaseolus vulgaris* with two indigenous rhizobial strains towards plant growth promotion, richness and structure of the *Rhizobiaceae* and total bacterial communities in the bulk soil was assessed. Both strains used induced a significant increase in nodulation and grain yield. T-RFLP profiling demonstrated that inoculation significantly increased the phylotype richness of bacterial communities in the bulk soil (outside the restricted rhizospheric area). No significant difference in richness between both strains used and no additive effect of co-inoculation were observed. However, differences between both inoculants and a clear additive effect of co-inoculation on heterogeneity were found. Both α and γ proteobacteria, together with *Firmicutes* and *Actinobacteria*, were enhanced by inoculation, while no evidence of TRF inhibition was found. The extent of these changes marked also the second crop season as indicated by the 32% increase observed in potato yield, and also by the 56% decrease in potato wireworm infestation. Therefore, rhizobia inoculation may contribute to the rotational benefits of legumes in potato cropping systems not only by providing fixed nitrogen, but also by increasing microbial diversity and structure, potentially stimulating plant growth promoting rhizobacteria and enhancing disease control. However, these effects depend largely on inoculant formulation.

Drivers of soybean rhizobia diversity in uninoculated soils of smallholder farms in Malawi

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Improving growth and production of nitrogen-fixing-legume crops in smallholder farming systems will lead to enhanced soil nutrient status and contribute increased agricultural yields and improved food security in these systems. This will require identifying competitive high performing local strains as well as an improved understanding of soil rhizobia ecology. This study is investigating biotic and abiotic factors that drive genetic diversity of soil rhizobia capable of nodulating promiscuous soybean on smallholder farms in Malawi. Soil was collected from 39 sites in the Ekwendeni region of Malawi known to vary in land use and cropping history. Soils were tested for texture, extractable P and organic matter as well as total N content. Soils were then

used as inoculants on promiscuous soybean variety TGX-1740-2F, locally named "Tikolore", grown in sterilized sand with a nitrogen-free nutrient solution in order to extract rhizobia. Total nodules, plant mass and total N fixed were determined. 20 nodules from each soil were randomly selected and rhizobia cultured. Stains were fingerprinted using repetitive element polymerase chain reaction (rep-PCR) using the BOX A1R primer. Molecular results were analyzed using GelCompar software to create phylogenetic dendrograms, and to generate diversity indexes for each site sampled. Soils were found to range widely in particle size, Mehlich-3 extractable P and total organic matter (OM) content. Rhizobia strains originated from diverse genera and represented both fast and slow-growing species. Diversity was found to correlate highly with field history.

Bio-slurry and inorganic fertilizers effects on soil properties and maize yield in Rwanda

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Continuous cropping without nutrient restitution under smallholder farms in Rwanda has led to serious nutrient depletion and reduced maize yields. This is further exacerbated by low soil organic matter and soil erosion. The smallholder farmers in Rwanda either do not obtain the necessary returns from fertilizer use to justify the costs or cannot afford to use inorganic fertilizers resulting in low inorganic fertilizer use. It is hypothesized that bio-slurry organic fertilizers are affordable, are of high quality and can be used to increase fertilizer use efficiency and crop yields for farming community in Rwanda. The objectives of this study were to determine the nutrient contents of bio-slurry as an organic fertilizer, to determine its effect on soil properties and to compare its effect and inorganic fertilizers on maize yield. A one year field study was carried out in Musanze District to test four levels of N fertilizers (0, 50, 100, 150 kg N/ha) and three levels of bio-slurry (0, 10, 20 m^3/ha) and their interactions. This constituted 12 treatment combinations laid out as a factorial experiment and arranged as a randomized complete block design with 3 replications using maize as the test crop. Slurry chemical analysis was done before planting to determine its nutrient content. Soil samples were taken before planting, at seedling, at tasseling and after harvesting to determine the following properties: organic carbon, total N, available P, soil pH, CEC, soil texture and aggregate stability. The maize grain yield was determined. Tukey's honest significance test was used to separate the means. Analysis of variance of maize grain yield showed significant differences ($P<0.05$) due to different treatments. The highest grain yield of 8022 kg ha^{-1} was in from at 100 kg ha^{-1} x bioslurry 10 m^3/ha treatment and the least was 5002 kg ha^{-1} of the control and 4997 kg ha^{-1} of urea 100 kg/ha x bioslurry 20 m^3/ha treatment. Soil total mineral nitrogen in the soil at seedling and tasseling was almost at similar level in all treatments. The differences were observed after harvesting. The highest amount of soil mineral nitrogen of 0.34% was observed in the urea 100 kg/ha x bioslurry 20 m^3/ha treatment and the lowest of 0.27% was observed under the control. Based on the results of this study, bioslurry is a good organic residue for soil nutrients management. The nutrients contribution of bioslurry was evidenced by increased maize yield and a slight change in soil physical and chemical properties. Resource poor farmers who cannot afford fertilizers may be encouraged to use bioslurry to improve the soil nutrient status. It is expected that the results obtained from this study will be used by extension staff for upscaling and farmers for increased production of maize to reduce food insecurity in Rwanda.

Effect of P and micronutrients on response of soybean to inoculation with rhizobia

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A greenhouse experiment and field trials were conducted to evaluate the effects of phosphorus and micronutrients on response of soybean to rhizobia inoculation on a fallow soil. In the greenhouse study, three nutrient levels: all nutrients (macro and micro), all nutrients minus phosphorus, and all nutrients minus micronutrients were used. The rhizobial inoculants used were 1495MAR, TSBF MIXTURE, Legumefix, HiStick, IRj 2180A, RACA 6, TSBF 560 and Biofix (Soybean). Two controls; positive (with mineral N) and negative (without mineral N), were included in the treatment. Symbiotic N_2 fixation was measured by the ureide method while nodulation and biomass were assessed at eight weeks after planting. The result shows that there is highly significant difference among all the parameters measured in terms of nutrient levels with all nutrients > all nutrients minus micronutrient > all nutrients minus phosphorus. However, there was no significant difference in terms of rhizobial inoculation except in the amount of N derived from atmosphere (Ndfa) which was highest with HiStick. In the field, only three inoculants were used; Legumefix, RACA 6 and TSBF MIXTURE while molybdenum was the test micronutrient. The effect of the nutrients on soybean productivity followed similar trend to that of the greenhouse study with all nutrients > all nutrients minus molybdenum > all nutrients minus phosphorus. In addition, rhizobial inoculation with Legumefix and RACA 6 gave the highest nodule number and nodule dry weight, respectively. The present study reveals that P addition is necessary to enhance benefits from symbiotic relationship between soybean and rhizobia even in a field that has been under fallow for many years.

Evaluation of plant growth and grain yield of 30 cowpea genotypes in Mozambique

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Cowpea (*Vigna unguiculata* (L) Walp.), is an important grain legume in Sub-Saharan Africa. The grain contains 25% protein and 64% carbohydrates and can potentially alleviate malnutrition among children of resource-poor African households. Current cowpea grain yields are low in traditional cropping systems due partly to limited access to improved varieties, crop and soil management practices and a complex of biotic and abiotic factor.This study therefore, assessed plant growth and grain yield of

30 cowpea genotypes grown in the field. Field experiments were conducted at two sites (Muriaze and Namialo in Nampula Province) during the 2010 and 2011 cropping seasons. Thirty cowpea genotypes were laid out in a randomized complete block design with four replications. Plot size of 9 m x 3 m with 1.0 m spacing between plots and 2.0 m between blocks were used. Cowpea seeds were planted at 75 cm between rows and 20 cm within rows. The data were then subjected to analysis of variance (ANOVA) and means separated using Fischer's least significant difference (LSD) at $p \leq 0.05$. Grain yield was much higher in cowpea genotypes IT04K-321-2, IT04K-227- 4, IT00K-126-3, IT-18 and IT97K-390-2. Grain yield differed significantly among cowpea genotypes at the two sites. Cowpea planted in the third week of January produced greater grain yield than those planted in the second week of February

Farmer participatory development of integrated striga and soil fertility management in Mali

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Striga hermonthica and soil fertility are frequently mentioned by farmers as two main constraints to cereal production in the Sahelian and Sudanian zones of West Africa. An integrated striga and soil fertility management (ISSFM) strategy that uses combinations of practical and simple control methods has high potential for success and application by farmers. However, ISSFM is knowledge-intensive and needs adaptation to the local cropping system. Cluster-based farmer field schools (CBFFS) for ISSFM were implemented in the district of Tominian, Mali and in the districts of Kati and Dioila in 2007 and 2010, respectively. The initiation of the CBFFS activities was planned in close collaboration with the national research institute and with farmer organizations in order to facilitate diagnostic meetings in villages, gain confidence and ensure active participation of farmers. During the farmer focus group meetings, local farmer practices (FP) for pearl millet (Tominian) and sorghum (Kati, Dioila) cultivation were determined, different striga control options were considered and subsequently, an ISSFM package was developed. This package consisted of application of organic fertiliser, micro-dose application of NPK or DAP fertilizer at sowing or crop establishment, intercropping of the cereal with cowpea or groundnut, micro-dose application of urea at 4-6 weeks after sowing (WAS) and additional weeding at the start of striga flowering (12-18 WAS). For sorghum, an adapted variety with striga resistance was added to the ISSFM package. The ISSFM package was tested against FP under supervision of a facilitator and with regular interventions by specialists. For two consecutive years, yield of pearl millet or sorghum, cowpea or groundnut were observed and the soil was sampled for determination of striga seed bank density in both practices after two years. A participatory cost-benefit analysis of FP and ISSFM options were performed with the farmers using harvest data and estimating labor and input costs for both practices. ISSFM reduced emerged striga and seed bank density and increased crop productivity and profitability in comparison to FP. The availability and cost of fertilizers as well as the difficulty of combining intercropping with animal drawn ploughs were indicated by farmers as important bottlenecks to the adoption of all ISSFM control options in its current form. Preference was given to the options that did not require cash investment such as organic fertilizer, intercropping and additional weeding. The cluster-based farmer field school proved very successful in stimulating not only technician-researcher-farmer knowledge exchange, but also farmer-farmer knowledge exchange. Farmer organizations are currently communicating the results and experiences of participants to large numbers of farmers through printed, video and radio messages and farmer exchange visits and "Striga handpulling" days. These organizations have also started selling seeds of improved varieties of sorghum and pearl millet as well as "striga control packs" to encourage farmers to try out the technologies on their own. There is a need to study and determine the impact of CBFFS on farmer knowledge and adoption of control options and ISSFM by farmer trainers, participants and non-participants within and outside intervention villages.

How farmer field schools and farmer-to-farmer videos empower farmers differently

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Power relations play a crucial role in the way people interact and learn from one another. We present experiences from farmer field schools (FFS) and farmer-to-farmer videos on integrated striga and soil fertility management (ISSFM) in West Africa, and describe how these methods affected farmer-extensionist-researcher relationships. Since 2006, ICRISAT and partners have organised cluster-based and conventional farmer field schools on ISSFM for sorghum and pearl millet in Mali, Niger and Nigeria, creating a wealth of data and insights. Depending on partners' and researchers' experiences and attitudes, ISSFM was established in either a participatory way through joint protocol development, or in more a top-down way with researchers deciding how technologies should be implemented. Irrespective of the style used, the basket of technological options was mostly pre-defined and little attention was paid to embed local innovations into the experimental design of FFS plots. Over the years, farmers learnt many things from their peers and facilitators, whom they appreciated and at times developed a friendship with. Researchers also learnt a few things, for instance to preferably start with local varieties when introducing ISSFM packages in field schools and to implement variety trials on the side before integrating the variety option into ISSFM, but they missed several opportunities to learn from farmers at the start of the FFS. When in 2011, ICRISAT staff and some of the FFS facilitators were trained in farmer-to-farmer video production, the need to fully understand and appreciate farmers' perspectives became apparent. For example, researchers were challenged to accept that tens of thousands of farmers in Niger had further reduced the recommended micro-dosing rate from 20-60 kg of fertilizer per hectare to about 2-6 kg per hectare. Moreover, farmers mixed these small quantities of fertilizer with their seed when applying to each planting hole: a practice that horrified some scientists due to the potential risk of the fertilizer burning the young seedlings, but that helped farmers save money and labour. In 2012, ten video modules (of about ten minutes each) were translated into six local languages (Bambara, Bomu, Fulfulde, Mooré, Hausa and Zarma) and some 20,000 multi-language DVDs were distributed via existing networks through a well-planned dissemination

strategy. Facilitated video viewings in villages (including old FFS sites) revealed that the videos created an enabling environment for farmers to share their own innovations. In a subtle yet powerful way, farmer-to-farmer video can play a role in stimulating farmer experimentation, counter-balancing the unequal power relations when setting up new Farmer Field Schools and setting research agendas.

Exploring options to intensify soybean production with smallholder farmers in Malawi

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Soybean (*Glycine max* L. Merr.) plays an increasingly important role in smallholder cropping systems in Malawi as a cash crop, to improve household nutrition and as a nitrogen-fixing crop in the cereal-based farming systems. Despite its potential, soybean yields on smallholder farmers fields are generally low due to recycling seeds of unimproved varieties, poor crop management and limited use of external inputs. This study was conducted to quantify the effects of inoculation, fertilizer application and compost manure on soybean yields in relation to the biophysical and socio-economic production environments of smallholder farmers. On-farm trials were established in the 2009 and 2010 growing seasons on 12 farmers fields per year per District in Dowa (1300 masl), Mchinji (1100 masl) and Salima (600 masl). Five plots of 100 m^2 were planted with soybean variety Nasoko with treatments 1) farmers practice, 2) inoculation with *Bradyrhizobium japonicum*, 3) inoculation plus 100 kg ha^{-1} fertilizer (N:P:K-Bo 10:18:24-0.1), 4) inoculation plus 300 kg ha^{-1} fertilizer, and 5) inoculation plus 100 kg ha^{-1} fertilizer plus 6 t ha^{-1} compost manure. Soil samples were collected and crop management practices recorded. A gross margin analysis was done for each technology by calculating the gross output and deducting the variable costs of production. Farmers perceptions were assessed by group discussions, individual questionnaires and technology ranking exercises. Average yields on farmer practice plots was 854 kg ha^{-1}. Inoculation increased yields to 949 kg ha^{-1}, inoculation with 100 kg ha^{-1} fertilizer resulted in 1260 kg ha^{-1} and with 300 kg ha^{-1} fertilizer to 1558 kg ha^{-1}. The combination of inoculation, 100 kg ha^{-1} fertilizer and manure resulted in yields of 1570 kg ha^{-1}. Yield levels varied significantly ($p<0.05$) between years and also between sites in 2010. More productive fields benefitted more from fertilizer application whereas less productive fields benefitted more from compost manure. Planting date, plant population, dates of first weeding and soil organic matter are the main factors explaining yield variation among farmers fields. The gross margin analysis showed that adopting the combination of inoculation, 100 kg ha^{-1} fertilizer and compost manure can increase profitability of soybean production by $120, $300 and $720 ha^{-1} for low, average and high farm gate prices respectively. Fertilizer rates of 300 kg ha^{-1} require high initial investment and are only profitable at higher market prices. Farmers in Mchinji and Salima ranked compost manure as the most preferred technology followed by fertilizer and inoculant whereas in Dowa, inoculant was ranked highest. Without access to credit, farmers prefer to allocate their limited resources to inputs for maize production. This study demonstrates that soybean productivity can be largely increased by application of external inputs and adoption will be profitable on the condition of good market prices for soya.

Impacts of phosphorus type and spatial relation to biochar on bean-mycorrhizal symbioses and crop phosphorus nutrition in a degraded Acrisol

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Biochar may have promise for enhancing plant-microbial associations in degraded and weathered soils of African smallholder systems. Previous work has shown a variety of plant responses to mycorrhizae (AM) in biochar-amended soils, and clearer understanding is needed of the way that soil fertility regime affects biochar/AM impacts, and of mechanisms through which biochar alters the plant-mycorrhizal symbiosis. We tested the interactions of AM, bean (*Phaseolus vulgaris*) plants, and biochar (hardwood, 450C pyrolysis temperature) under different phosphorus (P) fertility conditions in a P-fixing, Acrisol subsoil with a P-efficient bean variety (CIAT BFS 10) grown to flowering in a pot study. Phosphorus sources compared to controls were ambient P in the biochar feedstock (2 kg P·ha^{-1} equivalent), insoluble iron phosphate (Fe-P, 50 kg·ha^{-1} equivalent) and soluble sodium phosphate (Na-P, 50 kg·ha^{-1} equivalent). Fe-P and Na-P were applied to soil in a gradient of proximity to biochar: mixed with wood before charring (*Bef.*) adhered to biochar before this was applied to soil (*Aft.*), and mixed with soil before biochar addition (*Soil*), and a no-biochar control. With these P sources we compared beans inoculated with the AM *Glomus clarum* to uninoculated controls. Char pH effects, water limitation, and nutrient limitations other than P were controlled for. Bean P uptake, root/char flatbed scans, microbial biomass-P, and ergosterol as a fungal biomass marker tested the responses of the plant-fungal symbiosis to these biochar and P applications. Flatbed scans of roots and char and showed that roots were linked to char by AM hyphae, with char-root linkage strongly correlated to AM colonization. The Ergosterol biomarker indicated that fungal biomass was localized to a greater extent in biochar enriched with P. Bean P uptake increased with Na-P application, but was not affected by biochar or AM for Na-P *Aft.* or *Soil* treatments. For Fe-P at 50 mg·P pot^{-1}, biochar increased mean shoot P uptake from 3.1 to 3.8 mg·pot^{-1} and total P uptake of roots plus shoots from 5.3 to 6.2 mg·pot^{-1}, including a positive AM-biochar interaction in which AM increased shoot P 12% more with biochar than without biochar. With the exception of the Na-P *Bef.* treatment, localization of P on char (*Bef.* vs. *Aft.* vs. *Soil*) did not influence shoot or total P uptake suggesting general facilitation of mycorrhizae by biochar, and physical sequestering of P within Na-P *Bef.* biochar. However, in the Aft. treatments, mycorrhizal colonization was increased by 5% for Fe-P adhered to biochar, and reduced by 13% for Na-P applied to biochar, suggesting that root vs. AM uptake pathways for P were altered by the localization of P sources on biochar. Percent root length colonized by AM was also increased by biochar at low P levels. Microbial biomass P did not respond in a consistent way to biochar or mycorrhizal colonization, but increased between treatments without additional P (with or without biochar) and those where Fe-P or Na-P was applied.

Effect of planting time on soybean yield and biological nitrogen fixation in Southern Rwanda

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Soybean (*Glycine max*) is the second most widely grown grain legume in Rwanda after beans (*Phaseolus vulgaris*). The production is constrained by low soil fertility, limited access to fertilizers and improved varieties by farmers, and poor agronomic practices. Fine-tuning agricultural practices of soybean production though planting time can contribute to enhance both its yield and economic benefits. This study aimed at determining the effect of planting time on soybean grain yield and biological nitrogen fixation in Gisagara district, Southern Rwanda. On-farm trials were conducted during the season 2012A, in two sites namely Kansi in marshland and Kigembe on a hillside. The experimental design was the Randomized Complete Block Design with three treatments and eight replications. The treatments consisted of three different planting dates, T0 at the beginning of rainfall season, T1 ten days after, and T2 twenty days after. All experimental plots in Kansi received a combination of 5t/ha of farmyard manure (FYM), 18N-20P-0K and seeds were coated with rhizobium inoculants of USDA 110 strain (800 g/ha) while in Kigembe the FYM was not applied. Results have shown that the soil type is Ferralsol, with moderate pH (5.4), organic carbon (2.0%) and total nitrogen (0.23%). The yields of treatments were significantly different ($p<0.01$) where high yield was mainly due to T0 in almost all the sites and the lower yield due to T2. In Kansi, the grain yields were 1.6 and 0.6 t/ha while in Kigembe they were 0.50 and 0.20 respectively. From these results, we can recommend planting soybean at the beginning of rainfall as the best agricultural practices.

Farmers' knowledge and perception on climbing bean-based cropping systems in Rwanda

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Considering the variability of agro-ecological and social-economic conditions in the country, there is a need to understand climbing bean-based cropping systems. This study aimed at assessing farmers' knowledge and perceptions on the productivity and profitability of existing climbing bean-based systems. A formal and informal survey were conducted in four sites representing major agro-ecological zones producing climbing bean namely, Musasu, located in Central plateau, Nyamasheke in Impala, Musanze in volcanic land, Rwerere in Buberuka highland and Nyagatare in Eastern savannah. This study showed that existing climbing bean-based cropping systems are monocrops, and intercrops with maize, cassava and banana. Climbing bean monocrops are the dominant cropping system in more than 55% of target areas because it is more productive than intercrops. Farmers used *Calliandra*, *Pennisetum*, *Leucaena*, *Eucalyptus* and cassava trees as staking materials. Lack of staking materials, and inputs including improved seeds, fertilizers, pesticides and pest/diseases were the major constraints in climbing bean cropping systems. Agricultural policy should improve the supply system of all inputs in order to enable farmers to take full advantage of using improved climbing bean-based technologies.

Effects of organic and inorganic nutrient source on bambara groundnut in the coastal region of Cameroon

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Growth and yield parameters of bambara groundnut [*Vigna subterranea* L. Verdc. landraces: White Seed Coat (WSC), Black Seed Coat (BSC) and Light Red Seed Coat (RSC)] were evaluated under organic and inorganic fertilization in order to determine the field performance, for the improvement of smallholder agriculture in Cameroon. Four fertilizer application rates (0, 3, 6, 12 t ha^{-1}) of water lettuce (WL) and poultry manure (PM), and four fertilization rates (0, 100, 150 and 200 kg ha^{-1}) of N,P,K were used in a randomized block design experiment with four replications. Application of WL or PMat 12 t ha^{-1} significantly ($P<0.001$) increased leaf water content, plant dry weight and total chlorophyll content in RSC landrace. Application of PM at 12 t ha^{-1} increased significantly ($P <0.001$) the number of pods per plant, the number of seeds per pods, the 1000-grain weight, the grain yield, and the pod yield in RSC landrace. Significant ($P<0.001$) increase of plant dry weight was observed in all landraces at 100 kg ha^{-1} N, P or K fertilization. The fertilization rates above 100 kg ha^{-1} N, P or K led to a decline in yield in all the bambara groundnut landraces compared to the optimum 100 kg ha^{-1} N, P or K fertilization. RSC landrace showed better growth and yield than WSC and BSC landraces revealing a greater response of this cultivar to fertilization. WL and PM can be considered as valuable fertilizers and can serve as a suitable alternative to chemical fertilizer in the coastal region of Cameroon.

Effect of organic and inorganic fertilizers on leaf nutrient uptake and quality of tea

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Tea (*Camellia sinensis*), is one of the leading cash crop in Kenya and represents about 26% of the total export earnings. In tea production, fertilizer application is the most important input that determines yield and quality. The use of organic manures is being promoted because improper use of inorganic fertilizers has been associated with damage in the soil chemical and physical

properties and a decline in the soil organic matter leading to low nutrient retention. An experiment compared enriched cattle manures (OM; NPKS at ratio 1:2 and 1:4), organic manure (OM), and standard tea fertilizer (NPKS 25:5:5:5) which were tested in mature tea at rates of 0;75;150 and 225 kg N/ha in the east Rift Valley, Kenya. The results on leaf nutrient uptake showed an increase N content with increase in N rates, regardless of fertilizer type. P and K decreased with increase in fertilizer rate regardless of the fertilizer type. For tea quality, theaflavins (TF) and thearubigins (TR) decreased with increase in fertilizer rates regardless of fertilizer type, expect for caffeine which increased with increase in fertilizer rate. The NPKS treatment and enriched manures showed higher caffeine content than that of OM alone. The study concludes that enriched manure especially the OM:NPKS ratio 1:4 can be used in tea production due to the beneficial effect of organic manures in the soil.

Restoration of natural regulatory mechanisms of plant parasitic nematodes in intensively cultivated land

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The use of chemical nematicides has generated environmental and public health concerns triggering urgency in the search for alternative methods. This study was undertaken to determine the effect of land use on nematode destroying fungi and to identify soil fertility management practices that can be adopted to restore natural regulation of plant parasitic nematodes. Soil samples were collected from land under varying uses; forest, shrub, napier, maize/bean, and vegetable crops in Taita Taveta District. Nematode destroying fungi, which are natural enemies of plant parasitic nematodes, were isolated from the soil using the soil sprinkle technique. Nematodes were extracted from soil and identified to the genus level. Greenhouse and field experiments were conducted to evaluate the effect of cow manure, chicken manure and their combinations on nematode destroying fungi, nematode community and growth of tomato (*Solanum lycopersicum* L.). The frequency of ooccurrence of nematode destroying fungi and the nematode community were significantly (P= 0.05) affected by land use. Nematode destroying fungi were more frequently detected in intensively cultivated land under horticultural production. The diversity index of nematode destroying fungi was highest in land under horticultural cultivation followed by maize bean, napier, shrub and forest in that descending order. Numbers of parasitic nematodes were also higher in the intensively cultivated land under crop cultivation compared to the less disturbed soil in the forest. Application of organic amendments resulted in significant (P≤ 0.05) increase in occurrence of nematode destroying fungi. The nematode destroying fungi occurred at frequencies of 50, 29.4, 17.6 and 2.9% in soil amended with chicken manure, cow/chicken combination, cow manures and the control, respectively. Addition of organic amendments into the soil also resulted in an increase of bacterial and fungal feeding nematodes and reduction of plant parasitic nematodes. Specifically there was a 225, 96 and 62% increase in bacterial feeding nematodes and 391, 96 and 74% increase in fungal feeding nematodes in soil amended with chicken manure alone, combination of chicken and cow manure alone in that order. Numbers of plant-parasitic nematodes were 92% lower in soil treated with chicken manure compared to the control. It can be concluded that addition of organic amendments in the soil caused an increase in numbers of native nematode destroying fungi which might have led to a decline of plant parasitic nematodes.

The commitment to agricultural production by MEA Limited: a leading farm input supplier

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MEA Limited is a private company first established in 1977 to supply quality farm inputs to farmers for the purpose of improving crop production and accelerating agricultural growth in Kenya. Our larger vision is to become the leading farm input and cereal supplier in East Africa and to expand into other regions as well. We are currently one of the leading fertilizer suppliers in Kenya with a 40% market share and have outlets in Mombasa, Nairobi, Nakuru, Eldoret and Kitale. The Uganda, Rwanda and Tanzania markets are served directly from the Kenya trade corridor while we work directly with other distributors in Malawi, Zambia and elsewhere. Our factory in Nakuru has a state-of-the-art fertilizer bagging and blending facility two hours distant from Kenya's capital, with a capacity of 200,000 MT per annum. We also operate an adjacent fertilizer quality control laboratory. In line with the growing global demand for the organically grown food and the growing importance of grain and forage legume production, the company recently acquired rights in the production, marketing and distribution of the rhizobial legume inoculant BIOFIX® from the University of Nairobi. This factory is also located in Nakuru and guarantees at least one billion rhizobia per gram of inoculant. The BIOFIX® product line enables smallholder farmers to better afford quality bio-fertilizers for their cereal legume crops such as soybean, common bean, groundnuts green gram, lucerne and desmodium. By relying more upon biological nitrogen fixation, these households not only enjoy higher yields and better household and animal nutrition but also realize residual benefits in following crops. To enable farmers' better access to the product, we have trained 43 agro-dealers in collaboration with the N2Africa Program and established credit arrangements with 15 of them across Western Kenya. We have several other MEA distributors who purchase the product wholesale and retail at recommended prices. Most recently, we developed a specialized fertilizer blend, Sympal that contains P,K,S,Ca and Mg and maximizes the benefits of legume inoculation. Through these commitments, MEA is helping the grain and forage legume industry in Africa grow with the best combination of legume production technologies.

Field legume response to inoculation with rhizobium in South Kivu Province, DR Congo

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The success of biological nitrogen fixation by legumes in the field depending on the interaction between legume genotype x rhizobium strain x environment x management. The objective of this work was to test the inoculation response of five varieties of common beans and soybean to commercial rhizobium strains on a degraded and fertile soil in Ikoma and Bugorhe local areas, of Sud Kivu province, Democratic Republic of Congo. The trial was carried out in a split plot design in three replications, with inoculation and varieties as factors. P and K fertiizer, limiting factors for nitrogen fixation, were applied on all plots. Observations were made on percentage germination, plant height at 50 percent podding, pests and diseases, soil covering rate and yield. Results revealed that bean response to inoculation was low and differed between sites while soybean response to inoculation is greater and also varied between sites. Nitrogen supplementation showed that the fertile soil contained sufficient nitrogen, whereas other factors interfered in nitrogen fixation in degraded soils. There was no difference in bean yield between nitrogen supplemented soils and no nitrogen supplemented soils. As for soybean, yield was higher in nitrogen supplemented soils in the two locations. These results also provided guidance on the design of soybean need-to-inoculate trials which are now ongoing.

Putting indigenous bradyrhizobia to work for farmers in Kenya: Soyabean N credit to maize

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Nitrogen credit to maize is defined as the amount of nitrogen needed to obtain the same optimum yield as yield in a legume rotation. Nitrogen credit to cereals has been reported elsewhere. In Kenya, however, N credit to maize has not been quantified for commonly grown legumes such as soyabean. The contribution of promiscuous soyabean inoculated with indigenous rhizobia to soil N status and performance of succeeding maize (*Zea mays*, L.) was studied in a field experiment at Egerton-Njoro (LH_2) and Rongai (LH_4) in Rift Valley of Kenya from 2009-2010. The experiment was established in split plot design replicated four times at each site. Treatments included growing promiscuous and non-promiscuous soyabean during the short rains season (September-December) followed by maize in the long rains (March-July) season. During the short rains (precursor season), main plots received a blanket application of 60 kg ha^{-1} P but no applied nitrogen. Crop residues and vegetation of the weedy fallow were incorporated in the soil during seed bed preparation for the long rain season. Sub-plots were grown under 5 treatments: weedy fallow, maize (variety Duma), TSBF 531 inoculated to SB19, TSBF 531+TSBF 442 (1:1) inoculated to SB 19 and uninoculated local soyabean variety Nyala. In the long rains (test season), three levels N (0, 30 and 60 kg N ha^{-1}) were applied to main plots and maize was planted in all sub-plots. A blanket application of 60 kg ha^{-1} P was applied across all plots in test the season. Mean maize grain yield following promiscuous soyabean inoculated with TSBF 531 increased by 38.3% over that following maize, 20.6% following local soyabean, 18.5% following fallow and by 12.9 % following strain 1:1 mixture of TSBF 531 and TSBF 442. The study demonstrated that use of a promiscuous soyabean variety inoculated with elite indigenous bradyrhizobium in rotation with maize is a viable and preferable option to weedy fallows and maize-maize cropping sequences.

Effectiveness of rhizobia isolates from Kenyan soils in nodulation of soybeans

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Bio-prospecting for elite strains of rhizobia in Kenya capable of effectively nodulating "promiscuous" soybean is intended to improve legume inoculants for that host. To date, 70 isolates were recovered from different agro-ecological zones and eleven hosts, tested for symbiotic effectiveness in the greenhouse and compared to two soybean strains representing inoculant industry standards (USDA 110 and SEMIA 5019). Rhizobia-free vermiculite was used as media in three litre pots, inoculated with 1 ml of rhizobial broth and soybean plants harvested at early flowering. Most isolates nodulated promiscuous soybean (74%) while non-inoculated treatments did not. Isolates were assigned to four classes: ineffective (20%), partly effective (23%), effective (18%) and highly effective (13%). Those native rhizobia that outperformed industry standard USDA 110 were considered highly effective where Effectiveness Index (EI) = isolate shoot dry weight (dw)/USDA 110 shoot dw. The best isolates (and EIs) included NAK 176 (1.26), NAK 179 (1.25) and NAK 96 (1.24). These strains resulted in growth that compared favorably to a treatment receiving high levels of mineral N (EI = 1.25). Next, isolates that outperformed commercial strains are being tested in pot soil experiment in a screen house and the evaluation will also be done in the field, but the initial discovery of these candidate elite strains raises exciting possibilities.

Land degradation and its implication for delineating management zones in smallholder systems of Western Kenya

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Understanding the variation in productivity of the soils is the most logical starting point in the process of targeting any land management decisions. This study, conducted in western Kenya, sort to estimate maize production potential across different soil fertility conditions as a basis for defining management zones. The study adopted the Land Degradation Surveillance Framework (LDSF) - a comprehensive soil sampling framework that is based on block of 10 by 10 and clusters of plots to demarcate the sampling points. Soil samples were collected across the landscape in diverse cropping systems and analyzed for standard parameters. The soil chemical properties were interpreted against documented classes of fertility to determine extent of chemical degradation. QUEFTS (QUantitative Evaluation of the Fertility of Tropical Soils) model was used to estimate the nutrient supply, uptake and potential productivity of the soils of the cropping systems. Results of the soil chemical analysis revealed that only 3% of the croplands sampled had high carbon levels (>3%). Majority of the farms had moderate (1.5% - 3%) to low (0.5% - 1.5%) soil organic carbon levels. The soils in the study area were found to be acidic with pH below 7. Most plots sampled had low to moderate levels of K, medium to high levels of Mg but very low levels of Ca. Using carbon as a measure of soil status, 3% of the plots sampled were classified as high fertility (HF), 79% as moderate fertility (MF) and 18% as low fertility (LF). There was a wide variability in the potential nutrient supply of the soils across the three fertility classes. The potential to supply nitrogen (SN) was 154 kg/ha, 73 kg/ha and 46 kg N/ha for the HF, MF and LF fields respectively. The supply of phosphorus (SP) in the HF fields at 14 kg/ha was 100% higher than that observed in the LF fields. The potential of the soils to supply potassium (SK) was in the order LF>MF>HF. The actual uptake of N (UN) as a proportion of the supply of N (SN) was estimated at 37%, 60% and 71% for the HF, MF and LF classes, respectively. The uptake of P as a proportion of the potential supply of P was above 90% across the three fertility classes. Nutrient interactions involving P had the widest yield gap showing the importance of P fertilization in increasing productivity in the area. The HF soils had potential to produce 2,835 kg/ha of grain yield compared to 2,165 kg/ha for the MF soils and 1,628 kg/ha under LF soils. These yield levels are far much below the production potential of 8 t/ha observed under researcher managed conditions. Increasing production in the study area will require addressing the nutrient deficiencies observed through use of organic and inorganic nutrient sources. The assessment provides information about soil properties and yield from the different management zones which can be used for fertilizer and soil amendment recommendations as well as targeting soil sampling plans.

Effect of inoculation time on growth of two banana genotypes inoculated with commercially produced arbuscular mycorrhizal fungi

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Banana yield in East African highlands is threatened with pests, diseases and inadequate soil fertility. To overcome some of these constraints, use of environment-friendly growth enhancers is recommended. The study objective was to evaluate the effect of commercial inoculum of arbuscular mycorrhizal fungi on growth of banana in the post-flask period. Two banana genotypes, Kamaramasenge (AAB, sub-group Sukali Ndiizi) and FHIA 17 (AAAA hybrid) were inoculated with Rhizotech, a commercially produced inoculum of arbuscular mycorrhizal fungi at de-flasking, 2 and 4 weeks after de-flasking. The genotypes differed in their response to inoculation and inoculation time. All growth parameters from the non-inoculated control and inoculation at de-flasking had no significant differences for both genotypes. Kamaramasenge responded best to 2 and 4 weeks inoculation, and they had significantly increased height, width, fresh shoot and root weight, while inoculation had no effect on FHIA 17. The observed differences in banana genotype response to inoculation with AMF may be related to the district differences in root system development.

Beyond ISFM: A market-driven approach to profitable, sustainable farming

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An increasing awareness is developing that adoption of ISFM strategies is market-driven. Farmers want to optimize returns on investments in their farm enterprise, and minimize risks. Is the ISFM paradigm best-suited to developing market-driven strategies? ISFM is not explicitly a market-driven production methodology; rather, it is a soil fertility management paradigm aimed at maximizing agronomic use efficiency (AE) of applied nutrients. While AE (kg of produce per kg nutrient applied) can be a useful metric, a comparable but more valuable metric from a farmer's perspective is the VCR for nutrient use (value of the produce per cost of nutrients).While managing soil fertility is a fundamental aspect of profitable farming, costs and benefits associated with managing land opening, timely planting and weeding, pests and diseases, harvesting, and controlling post-harvest losses need to be given equal consideration. In this presentation, Commercialized Sustainable Farming Systems (CSFS) is presented as an alternate production paradigm to ISFM. While retaining the integration of improved germplasm, mineral nutrients, and organic inputs that characterize ISFM, CSFS evaluates all input and management options on a cost:benefit basis. As such, it is directed at optimizing profits and VCR, rather than AE, and considers management options that are not explicit and sometimes neglected under ISFM. The CSFS paradigm also considers costs and benefits of risk reduction strategies, including

herbicide/pesticide use and minimum tillage, which can reduce risks associated with large investments in nutrients and improved germplasm. Risk reduction is an important consideration in commercially-oriented farming systems where investments are greater. The point of CSFS is to take a more commercialized approach to developing our agronomic interventions, which emphasizes what is most important to farmers: increased profits and reduced risk. We discuss how this perspective changes the kinds of interventions we explore, what we measure in the field, and how we approach fertilizer subsidies.

Chickpea and lentil nodulating rhizobia indigenous to Ethiopia outperform imported commercial inoculants

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Chickpea (*Cicer arietinum*) and lentil (*Lens culinaris*) are important pulse crops commonly grown at mid-altitude and highlands of Ethiopia, usually as rain-fed crops. These pulses, while providing an excellent source of protein for the resource poor farmer, also represent an important source of cash income for smallholder producers. However, the national grain yield of the crops is extremely low, only ranging from 0.6-0.8 t ha^{-1}. Often, this is associated with decline in soil fertility and lack of compatible rhizobia. The present study was conducted to assess the population size (MPN method) of chickpea and lentil rhizobia in selected locations in southern Ethiopia, to isolate, characterize and evaluate the symbiotic effectiveness of the isolates on different cultivars (Chickpea: Natoli and Shasho; Lentil: Teshale and Alemaya) under greenhouse and field conditions. For comparison, elite national (EAL029A and EAL600) and imported commercial Canadian inoculants (2006005A and 2006001A, Canadian) were included in the study. The population size of indigenous rhizobia compatible to these crops varied at different locations ranged from 0 at Ele and Alaba to less than 500 at Bodity, and $1.7x10^4$ cells g^{-1} of soils at Jole, thus indicating the need for inoculation at three of the locations studied. Overall, a total of 104 chickpea and 114 lentil nodulating rhizobia were isolated from soil samples collected from diverse agroecological locations in central and southern Ethiopia. Results from phenotypic characterization on the collection showed indigenous rhizobia nodulating these pulses constitute physiologically and metabolically diverse groups, thus indicating biodiversity of the microsymbionts *in situ* and the potential that exists for selecting and developing efficient inoculants. Symbiotic effectiveness of the test isolates in the greenhouse, as determined in percent dry matter accumulation relative to N fertilized (positive) control treatment, varied significantly, ranging from 25 to 129% and 26 to 99% on lentil and chickpea, respectively. Experiments on farmers field, involving inoculation treatments (selected isolates, elite national and imported inocula), N+ and N- fertilizer controls, indicated that indigenous isolates such as Cp41 and Lt29 excel elite national and imported inocula in their symbiotic performances. Accordingly, Cp41 and Lt29 produced 10- and 5-fold more nodule dray mass over the control treatment and elite inoculants on chickpea and lentil, respectively. Similarly, chickpea and lentil inoculated with Cp41 and Lt29 yielded 18% and 41% more grain yield over the elite national and imported inoculant in field conditions, respectively. The study, while demonstrating inoculation with appropriate rhizobia enhances grain yield on target crops, it also indicated the potential of indigenous biodiversity resources for selecting efficient strains to promote BNF among smallholder producers.

Genetic and symbiotic diversity of rhizobia in Ethiopian soils: an untapped biological resource to enhance N2-fixation to benefit smallholder farmers

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Rhizobia are a key resource as all contributions to the nitrogen budget in agricultural systems depend on their nitrogen fixing capacity. The taxonomic diversity of this group of rhizobia is large, and there are also large variations with respect to their nitrogen fixing efficacy in symbiosis with different legumes. Our research group possesses a steadily expanding biobank of rhizobial isolates (at present ca. 500), sampled from legume crops and trees growing in different agro-ecological zones in Southern Ethiopia. Based on Multilocus Sequence Analyses (MLSA) and phenotypic approaches, we have identified that Ethiopian soils harbor diverse groups of rhizobia that are very distinct (more than 80%) from the hitherto known taxa of the family *Rhizobiaceae*. Recently, we have reported a large number of new genospecies within this collection, including seven novel linage (I –VII) within *Ensifer* and three new species described within the genus *Mesorhizobium*. Cross inoculation experiments in the greenhouse and farmers fields, involving inoculation treatments (selected isolates, elite national and imported inocula), on crop and tree legumes indicated that some of the indigenous isolates excel (over N+ control, elite national and imported inoculum strains) in their symbiotic performance. These results, while suggesting the enormous untapped rhizobial resources resident in Ethiopian soils, indicate ample opportunities for selecting elite strains to enhance effective rhizobium-legume symbiosis in its agro-ecosystems. Further, the challenges and prospects associated with the exploitation of biological nitration fixation in the country in general, and the potential to develop and promote broad-host range inoculants to small-scale farmers will be discussed.

The *B*-value and isotopic fractionation during N2 fixation by faba beans

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Quantifying biologically-fixed nitrogen by legumes through the 15N natural abundance techniques requires the determination of *B* value (δ15N value for a legume when completely dependent on N2 fixation for growth). With this objective, faba bean seeds of six varieties (CS-20DK, Degaga, Gebelcho, Moti, Obse and Walki) were inoculated with *Rhizobium fabae* strain LMG23997-19. The plants were grown in vermiculite with an N-free nutrient solution in a growth room. At full flowering, plants were harvested and separated into nodules, roots and shoot components to analyze total N and 15N content and determine the isotopic fractionation (*B* value) by the different plant parts. Owing to its large seed size and high N content, the seeds sown were also analyzed for total N and 15N to account for seed 15N contribution by seeds. Results showed that the shoot N concentration was not significantly different between the six varieties but it was significantly different for the root and nodule parts. Each variety showed different 15N discrimination for the different plant parts analyzed. Strong and significant discrimination was observed between the nodules (in the range of +3.58 ± 0.95‰ for variety Degaga to +7.00 ± 1.31‰ for variety Moti) and the rest of the plant parts (shoots and roots) in which case the values were always negative (ranging from -1.06 ± 0.35‰ in shoots of CS-20DK to -0.18 ± 0.22‰ in shoots of Moti). The uncorrected $B_{whole\ plant}$ value, without considering seed N, ranged from -0.78 ± 0.05‰ in Gebelch to -0.17 ± 0.09‰ in Moti. However, given the importance of the amount of seed N in faba bean, seed 15N contribution was considered in the calculation of the *B* value using a mass balance model. In this case, the corrected $B_{whole\ plant}$ value, discounting the seed's excess 15N content, varied between -1.83 ± 1.56‰ in Degaga to +0.48 ± 0.35‰ in Walki which confirmed the existence of a significant isotopic discrimination of N during N2 fixation among the varieties. The variation in *B* values (δ15N) value of shoots and whole plant justify the need to estimate δ15N of plants grown in N free medium for accurate assessment of BNF by field grown faba bean plants when 15N natural abundance technique is used. Our results also suggest that the *B* values determined for the different faba bean varieties are appropriate to be used in BNF studies via the 15N natural abundance under field conditions.

Response of wheat to fixed nitrogen by preceding faba bean and applied P grown in rotation in the tropical highlands of southwest Ethiopia

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Nitrogen fixation by legumes is a low-cost alternative to N fertilizers for smallholder farmers in Africa. Legume–cereal rotation is an important component of the cropping systems of smallholder farmers in the highland agro-ecological zones of Ethiopia. However, little is known of the effect of faba bean on the performance of subsequent wheat in the rotation. A field experiment was conducted in the tropical highland conditions of southwest Ethiopia in two phases. In the first phase, three faba bean varieties (Degaga, Moti, Obse) and a local variety were evaluated for grain yield, biomass production and nitrogen fixation (via 15N natural abundance method using a locally adapted wheat as reference crop), as affected by Phosphorus (P) fertilization (0, 10, 20 and 30 kg P ha^{-1}). In the second phase, the effect of faba bean fixed nitrogen on biomass and grain yield of the subsequent wheat crop was assessed in a rotation. In the first phase, faba bean grain yield ranged between 3.8±0.8 and 4.4±0.6 t ha^{-1} with no significant yield differences among the varieties and P applications. The average proportion of N2 fixed ranged significantly between 72 ± 2.8% for variety Degaga and 94 ± 3.9% for Moti. This resulted in average amounts of N2 fixed ranging between 258 ± 22 and 387 ± 33 kg N ha^{-1}, with an average N2 yield of 358 ± 35 and 410 ± 43 kg ha^{-1}, respectively. The amount of soil derived N ranged from 48 ± 4.4 to 68 ± 3.2 kg N ha^{-1}. The net N contribution of the faba bean varieties to the soil (after adjusting for N export in grains) was highest for Moti (189 ± 16 kg N ha^{-1}), which is equivalent with the N content in 1 ton NPK (18%N) mineral fertilizer. Wheat grain yield after faba bean without application of mineral N fertilizer ranged significantly between 1.8 ± 0.4 t ha^{-1} (with Degaga-wheat rotation) to 2.8 ± 0.4 t ha^{-1} (with Obse-wheat rotation) that corresponded to 17.6 and 81.7% yield increase, respectively, relative to the yield of wheat grown after wheat. P application to the preceding faba bean varieties also significantly improved the grain yield of the succeeding wheat grain yield that ranged between 2.0 ± 0.6 to 2.8 ± 0.5 t ha^{-1}. In conclusion, faba bean can be grown as an alternative crop to fallow in the highlands for the economic benefit of farmers through improving soil fertility to sustainably intensify subsistence production systems where fertilizer inputs are unaffordable or unavailable.

Smallholder engagement in Kenya's emerging soybean industry

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A soybean industry that is increasingly dependent upon smallholder production rather than importation is emerging in Kenya. Presently, Kenya processes about 120,000 tons of soybean per year, most of which is imported. Research and development efforts by the N2Africa Program are assisting smallholders in west Kenya to enter soybean production by promoting new crop varieties, legume inoculants and accompanying technologies. To date, 29,222 households have explored soybean production, 63% receiving small technology test kits deployed on 200 m^2 and the remainder practicing larger scale cultivation (mostly on 0.2 ha). The preferred varieties are promiscuously nodulating SB 19 and 25, with over 127 tons of seed produced through 87 community-based multiplication efforts and more recently the specifically nodulating SeedCo pre-relese varieties Saga and Squire. All varieties respond to inoculation with commercially-available BIOFIX containing *Bradyrhizobium japonicum* strain

USDA 110, to date over 1.33 tons of legume inoculant were applied as 10, 20, 50 and 100 g packets. The Sympal fertilizer blend containing P, K, Ca, Mg and S but lacking nitrogen was developed after nutrient deficiency symptoms were noted on plants receiving only SSP. Together, BIOFIX and Sympal increase soybean yields by 710 kg ha^{-1} compared to SSP alone, increasing root nodules and crown nodulation by 156% and 42%, respectively. Training was offered to 47 area agro-dealers in the use, handling and marketing of these products, and BIOFIX and Sympal extended to many of them on credit. To backstop this effort at the grassroots level, 87 Master Farmers belonging to 24 local organizations were trained in BNF technology, 224 demonstrations installed, and 16,150 extension materials distributed. In addition, 25 sets of grain processing kits consisting of scales, moisture meters, tarpaulins and branded sacks were deployed. Earlier in 2012, a buyer sought soybeans and 16 cooperating farmer groups quickly bulked and sold 262 tons worth $164,000 while retaining 81 tons of seed for the following season. Soymilk is being prepared in several local communities using a simple mince-and-press technique with nutritional benefits already observed among the most vulnerable orphaned children. Clearly, soybean enterprise has taken root among Kenyan smallholders with multiple benefits to rural communities.

Arbuscular mycorrhizal fungal communities differ between co-occurring indigenous tree species

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The Afromontane forests in Ethiopia are composed of a number of indigenous tree species which are declining at an alarming rate. Consequently there is a need to maintain the forest genetic resources and the associated mycorrhizal fungal community through reforestation activities using indigenous tree species. However, for successful reforestation using indigenous mycorrhiza and tree seedlings, knowledge in the diversity and community composition of arbuscular mycorrhizal (AM) fungi associated with distinct plant species co-occurring in these natural forest ecosystems are crucial. Furthermore, such a knowledge helps towards the understanding of the ecological role of AM fungi on plant species co-existence and ecosystem functioning. Studies carried out in the Afromontane forests of Ethiopia showed that the indigenous trees are dominantly associated with AM fungi. Molecular AM fungal diversity analysis of mycorrhizal fungal associated roots also indicated that the AM fungal communities differed significantly among co-occurring tree species and forest sites. Interestingly, the AM fungal communities were largely composed of native and new fungal taxa. These native fungal communities were also trapped from rhizosphere soils by seedlings of the same studied plant species, implying the trapping potential of indigenous tree species.

Assessing tree effects on soil characteristics in agroforestry parklands in Burkina Faso

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It is known that root development of the plants depends on the genotype but also on soil physical and chemical characteristics. Indeed, the soil content in mineral elements is a determining factor in root development of the plants and thus their growth. However very few studies were interested in studying the soil characteristics in plant-soil-water interactions in agroforestry systems due to the high cost of the analyses using the conventional method, especially when a very large number of soil samples is involved. The present study employs an innovative technique of soil analysis called Near Infrared method in view to study the influence of different trees species on soil properties in agroforestry parkland systems. In this study soil samples were taken under two parkland species at three distances from tree trunk and in an open area serving as control. Samples were taken 10 cm intervals down to 50 cm deep. The results of the analysis show that soil characteristics are different under different trees species. Under the same tree species, differences in soil characteristics were observed according to distance from tree trunk and soil depth. Finally the results of the study showed that the soil physical and chemical characteristic is improved under trees compared to the open area. These differences observed in soil physico-chemicals characteristics have then implications in crop growth and crop yield.

Placement de l'urée et amélioration de l'efficacité d'utilisation de l'azote en riziculture irriguée

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Des essais en station et en milieu paysan ont été conduits sur la plaine rizicole de Karfiguéla au Burkina Faso en vue d'évaluer la contribution du Placement Profond de l'Urée (PPU) et de la fumure organique dans l'amélioration de l'efficacité d'utilisation de l'azote en riziculture inondée. La plaine rizicole de Karfiguéla est localisée dans la région des cascades à une dizaine de kilomètres de la ville de Banfora. Pour l'essai en station, les performances agronomiques et l'absorption azotée dans le PPU ont été comparées à celles de l'urée simple fractionnée en fonction de trois densités de repiquage (20 cm x 10 cm, 20 cm x 15 cm et 20 cm x 20 cm). Trois variétés de riz ont été utilisées (Tox 728-1(FKR 19), WAS 161-B-9-3(FKR 56N) et WAS 122-IDSA 1-WAS 6-1(FKR 62N)). Un dispositif expérimental en split plot a été utilisé les parcelles principales étaient représentées par la combinaison variétés x densités et les fumures disposées en parcelles secondaires. Les meilleurs traitements identifiés ont été comparés en milieu paysan aux pratiques des producteurs suivant un dispositif en blocs dispersés.L'analyse des performances agronomiques a montré que les meilleurs rendements sont obtenus avec le PPU dans les parcelles repiquées à la densité de 20 cm x 20 cm avec les variétés de riz FKR 19 et FKR 56N. En milieu paysan, l'apport de matière organique a augmenté sensiblement les rendements comparativement à ceux obtenus en station et aux pratiques des producteurs.L'évaluation du statut azoté par le «Leaf color chart» durant la phase végétative a montré que le feuillage du riz des parcelles PPU est resté dans les limites de coloration ne nécessitant pas un apport complémentaire d'azote à l'inverse des parcelles fertilisées à l'urée simple fractionnée.

L'analyse des indices d'absorption de l'azote a montré un meilleur taux de recouvrement de l'azote dans les parcelles USG à la densité de 20 cm x 20 cm. Il est également ressorti une forte corrélation entre l'azote absorbé et le rendement au contraire de l'azote apporté où la corrélation était très faible.Au regard des résultats obtenus, le placement profond de l'urée peut contribuer significativement à l'amélioration du rendement du riz à Karfiguéla. Des résultats bien meilleurs pourraient être obtenus avec l'utilisation d'une bonne dose de fumure organique adaptée à d'autres technologies telle que le Système de Riziculture Intensive (SRI).

Environmental, technological and food security characterization of cowpea cultivation in Mali

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To ensure food security in Sahelian countries, cowpea (*Vigna unguculata* Walp. L) is used in different cropping systems as a grain legume to improve soil fertility through practices and management techniques. In order to promote cowpea industry in Mali, this study aimed to characterize the cowpea cultivation system on environmental, technological and food security bases. As methodology agro-ecosystems diversity, climate data, soil diversity, biotechnological tools and multidisciplinary and participatory approach were considered. In environmental terms, cowpea is grown both in rural and urban areas. Climate variability and diversity (200mm to 900mm), soil characterization and genetic diversity of cowpea varieties showed that *V. unguiculata* has advantages for the development of technological options as microbial inoculant technology or way to face environmental constraints and climate change. Technologically, the cowpea cropping system is characterized by a diversity of cultivation practices of local land management, use of genetic diversity of improved varieties, development of techniques and biotechnologies of soil fertility, improvement of pod and seed yields (1190-3500 kg ha^{-1}) and forage production under higher plant density. The study pointed out that these practices and technological options can be valued in accordance with local realities and environmental conditions. It suggests the need for the development of innovative strategies in the field of climate change and food security. In terms of food security, we found availability of improved and certified seed as critical. Effectiveness of the participatory approach resulted in an effective involvement of 18 researchers from North and South countries, civil society and 35 associations and farmers' organizations able to conduct evaluation studies and dissemination of technology, supporting research in Mali. Women occupy a key role in the development of the cowpea value chain. In the context of advancing the cowpea industry in Mali toward agricultural production and diversification, this study shows the need: i) to organize the players for cowpea cultivation, ii) to strengthen staff training in seed technology including seed protection and intellectual property rights and iii) to seek and innovate in cropping systems options and biotechnology transfer by seed processing, preservation and protection against predators and diseases within the context of Sahelian environmental conditions and climate change.

Improving maize productivity: An option for rice husk biochar in Ghana

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Poor soil fertility is a key constraint to improving farm productivity and farmer livelihoods in sub-Saharan Africa and the search for sustainable soil management practices continue. Biochar, a pyrolysed biomass product, in recent years has gained international recognition to improve soil productivity. There is however limited research on biochar in Ghana to warrant government policy. A field study was conducted in the major season of 2012 in the semi-deciduous forest zone and the Guinea savanna agro-ecological zones of Ghana. The objective was to determine soil management scenarios that will enhance the beneficial effect of biochar application to soils. The treatment were control no amendments, 2 t/ha biochar and 4 t/ha biochar. Each main treatment received 0, 30, 60 and 90 kg N/ha. The test crop was maize. 4 t/ha biochar + 90kg N/ha increased maize yield across sites. Biochar increased N use efficiency and improved gravimetric soil moisture contents across both sites. Biochar should be explored as the organic component in integrated soil fertility management for a sustainable Africa Green Revolution.

Effects of integrated soil fertility management practices on soil hydraulic properties in Ethiopia

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We have studied combined and separate additions of compost and fertilizer on Humic Andosols in the central highlands of Ethiopia for five years and found consistently higher yields for treatments that combine half-dose of fertilizer and half-dose of compost compared to full dose of either compost or fertilizer alone. The objectives of the present study were to investigate if the effects of compost on soil hydraulic properties and related surface soil characteristics can explain the differences in crop yield. The on-farm field experiments have 4 treatments (control (0), full compost (C), ½ compost combined with ½ fertilizer (CF) and full fertilizer (F)) each in a randomized complete block design with three replications. The experiment is also replicated across farm fields on three farms. The infiltration rate was measured with ring infiltrometer. Results showed that both the infiltration rate and cumulative infiltration significantly varied with treatment ($p<0.001$) with a significant interaction effect ($p=0.031$). The infiltration rate was higher in the C treatment (1.51 ± 0.18) followed by the CF (1.33 ± 0.17) in comparison with the 0 and F treatments.. The dry soil bulk density (g/cm^{-3}) was significantly lower ($p<0.001$) in soil amended in C (0.85 ± 0.017) and CF (0.94 ± 0.019), due to the stimulating effect on soil aggregation and higher C content. The differences in the antecedent moisture

content and aggregate sizes, which decreased with increasing organic matter content, were likely to be the principal factors influencing the hydraulic properties. Although the studied soils are naturally high in soil organic matter, the treatments with compost have a measurable effect on the soil physical properties. However, since there is an evident dose-response relationship the effects on the soil physical properties cannot alone explain the crop harvest synergy between fertilizer and compost addition.

Symbiotic nitrogen fixation and soil nitrogen balance as influenced by groundnut genotypes and nitrogen fertilizer in the Nigerian savanna

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Smallholder farmers in the savannas of Nigeria rarely apply nitrogen (N) fertilizer to groundnuts (*Arachis hypogaea* L.) despite recommendation for modest application due to low inherent soil N. A non-nodulating groundnut genotype (ICGL 5) was used to estimate symbiotic N fixation and soil N balance within ten genotypes at 0 and 30 kg N ha^{-1} using the N-difference method. Generally, application of 30 kg N ha^{-1} resulted in higher N_2 fixed in the groundnuts than at 0 kg N ha^{-1}. However, the increase was not significant in one of the genotypes, SAMNUT 21 which also had lower amount of Ndfa at 30 kg N ha^{-1}. The highest increase due to N application was observed in genotype, SAMNUT 23. ARROSS ICGX 00020/5/P_4/P_{10} had the highest amount of N_2 fixed at 0 kg N ha^{-1} while Ndfa slightly responded to N application in this genotype and SAMNUT 22. All the genotypes had negative N balance at 0 kg N ha^{-1} and only three had a positive N balance at 30 kg N ha^{-1}. This was attributed to low amount of N_2 fixed because N application had little impact on grain N uptake. The highest yielding genotypes in this study are ARROSS ICGX 00020/5/P_4/P_{10}, SAMNUT 22 and SAMNUT 23. Grain yields of ARROSS ICGX 00020/5/P_4/P_{10} and SAMNUT 22 could be sustained under low soil N conditions while fertilizer N application is required to increase grain yield of SAMNUT 23. The present study reveals that great variability exists in the productivity of groundnut genotypes at different mineral N levels and also the challenge to improve the symbiotic effectiveness of groundnuts to fix atmospheric nitrogen.

Determinants of soybean market participation by smallholder farmers in Zimbabwe

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Market linkages have been identified as key to the successful integration of grain legumes into the smallholder farming systems of Southern Africa. Soybean (*Glycine max*) is a high value crop that has shown great potential to sustain production systems in smallholder farming systems due to its multiple roles of cash income, food and soil fertility management in cereal-legume rotations. The net income benefits derived from soybean production depend on the extent to which farmers participate in output markets. It is therefore necessary to identify the key determinants of soybean market participation by farmers in order to be able related to key entry points that increase income. Using a sample of 187 smallholder farmers in Guruve district, the study employed the Heckman's Probit model with sample selection to; firstly identify the factors affecting a farmers' decision to participate in soybean markets, and secondly evaluate the factors that affect the intensity of a farmers participation in soybean output market. Results from the study suggest that the use of inoculants and certified soybean seeds results in high yield which in turn improves a farmer's chances of participating in soybean markets. Furthermore, farmers who have access to extension services and output prices have higher chances of participating in markets than their counterparts. Ownership of radios also improves access to information on weather and market information and thus improves the likelihood of farmers' market participation. However, the results also show that male-headed households are more likely to participate in markets than female-headed households. Based on these findings, we recommend that household market participation in soybean markets could be improved by improving access to inoculants, certified seeds for soybean, farmer to extension worker ratio and access to market information such as prices.

Enhancing maize productivity in smallholder irrigation systems under water and nutrient limiting conditions in southern Malawi

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Water scarcity, seasonal and mid-season droughts, and soil N deficiency are the key constraints to crop production intensification in the semi-arid Shire Valley region of Malawi. Maize yields have remained low despite investment in irrigation infrastructure to support farmers intensify crop production. Increased agricultural productivity in the smallholder irrigation systems will require increased efficiency with which both water and nutrient resources are utilized. Currently, smallholder irrigation farming systems base irrigation schedules on arbitrary observation of crop performance and soil moisture, leading to poor productivity of scarce water resources. Fertilizer use is also very low despite the high potential for maize production under irrigation. This study was conducted to assess options for increasing water and nutrient use efficiencies in the production of maize in the Shire Valley through improved management of irrigation water, improved understanding of the interaction between nutrient and water use efficiency, and application of both conventional and isotopic techniques to partition transpiration and evaporation with the aim of enhancing water use efficiency of the crop. A factorial experiment was conducted for two seasons with three irrigation treatments; 50%; 100% and 150% Crop Evapotransipiration (ETc) and three nitrogen (N) fertilizer treatments (0, 50 and 150 kg N ha^{-1}) were carried out. A control treatment with no irrigation and fertilizer was also included. All

treatments consisted of three randomized replicates. Irrigation and rainwater samples were collected over the season for δ18O analysis. A simple isotope mass balance model was used to determine the fractions of water lost through soil evaporation and leaf-transpiration. Maximum maize yields of about 6 t/ha were achieved with 150% ETc irrigation and 150 kg N/ha. Yields were least (< 0. 5 t/ha) it the control treatments without supplimnetary irrigation and N application. There was a strong interaction between irrigation amount and N application rate. Irrigation at 50% ETc resulted in an increase of yields from about 0.5 to 1.3 t ha^{-1} for zero fertilizer treatments, indicating that mosture was strongly limiting productivity. Application of N led to increases of yields of between 1 to 1.5 t ha^{-1}, with the effects of N increasing with increased water supply. Water use efficiency was highest under 50% ETc and least at 150 ETc irrigation. Also water use efficiency increased substantially with increase in N application. The values of δ18O ranged from -3.2 to 7.5‰, which is more enriched than the δ18O in the rainfall and irrigation water, which were found to be quite similar at -1‰. Transpiration accounted for 20-25% of water lost in the first 50 days of the season, indicating majority of the water lost was through soil evaporation. The results clearly showed that there is potential for enhancing maize productivity in smallholder irrigation systems in southern Malawi by optimizing water and N management. Efforts are required to build capacity of farmers and extension systems to adapt best nutrient management practices for enhancing crop production. The International Plant Nutrition Institute together with research, development and fertilizer industry partners are implementing a research and development program to establish and promote best management practices based on the 4R Nutrient Stewardship concept. This concept that defines the right source, rate, time, and place for fertilizer application, provides a simple and effective guideline for communication in fertilizer management practices in Africa in variable cropping systems.

Biological nitrogen fixation of introduced soybean varieties inoculated with *Bradyrhizobium japonicum* in Benin

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Isotopic dilution method was used to estimate biological nitrogen fixation (BNF) of fourteen soybean varieties inoculated with Bradyrhizobium japonicum using maize as reference plant. The study was carried out at the Application and Production Farm of the Faculty of Agronomic Sciences located at Sekou in southern part of Benin from July to October, 2009 on a typical "terre de barre" soil, classified by Food and Agriculture Organization-United Nations Educational, Scientific and Cultural Organisation as Rhodic Ferralsol. The percentage of Ndfa varied from 72.2% (BRS 261) to 95.8% (BRS 262). The amount of N fixed ranged between 35.1 kgN/ha (BRS santacrutz) and 153.5 kg N/ha (Canarana). In a scenario where the soybean shoot dry matter and grains was removed from the field after harvest and only the fallen leaves are incorporated into the soil, N budget ranged between -177 kg N/ha (Canarana) and -66 kg N/ha (BRS 260). When only soybean grains are exported from the fields and fallen leaves and shoot dry matter are incorporated into the soil, N budget varied from -8 kg N/ha (BRS Santacrutz) to 145 kg N/ha (BRS garantia). The study showed that Canarana, Jenguma, TGX1448-2E and BRS garantia soybean varieties were identified as the highest amount of N fixed capacity among the 14 varieties. From the results, it could be concluded that the inclusion of Canarana, Jenguma, TGX1448-2E and BRS garantia soybean varieties in cereal-based cropping systems would help reduce N inputs and improve soil and crop productivity in farming systems in Benin.