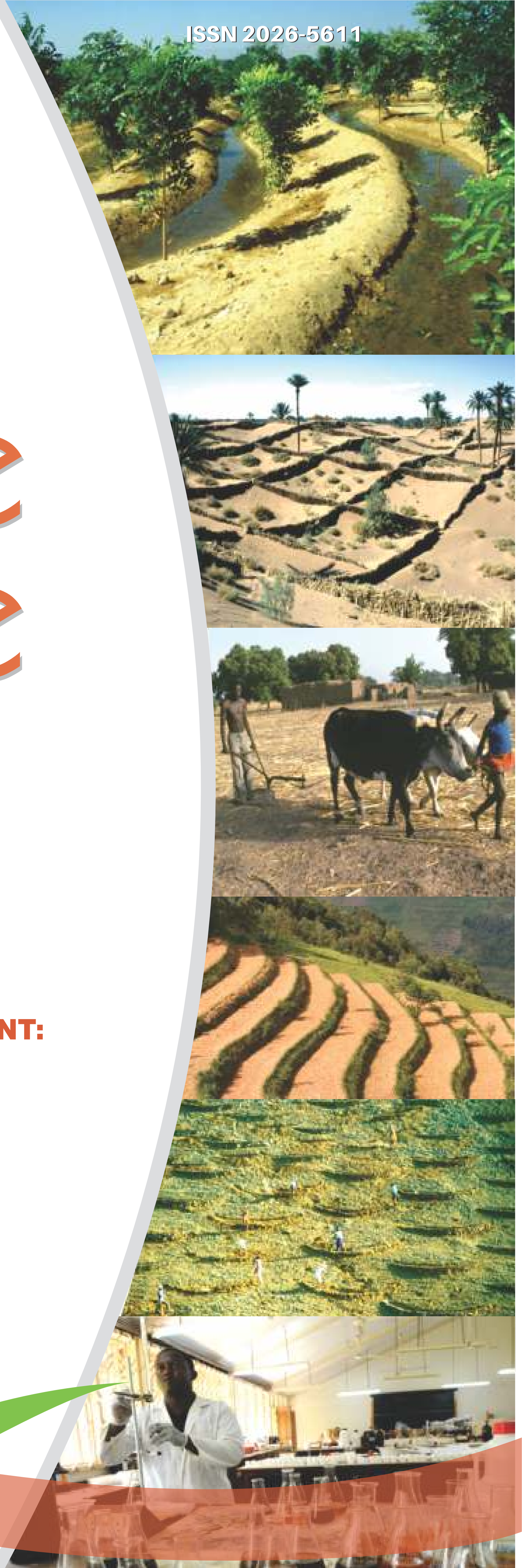
ISSN 2026-5611

Food and Agriculture Organization of the United Nations

Nature & Faune

Volume 30, Issue 1



SUSTAINABLE SOIL MANAGEMENT:

Key to food security and nutrition in Africa

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Nature & Faune

Enhancing natural resources management for food security in Africa

Volume 30, Issue 1

Sustainable Soil Management:
Key to Food Security and Nutrition in Africa

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Regional Office for Africa
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Accra, 2015

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Special edition of Nature & Faune journal for 2015 International Year of Soils

ISSN 2026-5611

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Rows of trees planted along the banks of irrigation and drainage canals in the city of Luxor, Egypt.

Photo Credit: @FAO/Rosetta Messori

MESSAGE TO READERS

Bukar Tijani[1]

The United Nations declared 2015 as the *International Year of Soils*. As a contribution to marking this event of global importance, this special issue of *Nature & Faune journal* addresses the central theme "Sustainable soil management: a key to food security and nutrition in Africa".

The quality of Africa's soils

Africa is said to have wonderful natural agricultural resources which can enable it to "feed the world". This potential needs to be pursued and solutions sought to overcome obstacles to making it a reality. Extensive areas of Africa are arid and semi-arid, with low and erratic average rainfall, low biomass production and consequently low organic matter content of the soils. This is however balanced out in the humid tropical areas of central and eastern Africa where the rainfall and soil fertility is high.

Africa has very rich alluvial soils along most of its rivers. With appropriate irrigation the potentials of these areas, e.g. in – the mountains of central/east Africa, (Rwanda, Burundi, Uganda etc.) and vast areas of Zimbabwe and Democratic Republic of Congo, which are endowed with excellent agricultural soils, can be maximally exploited. This edition encourages development to favour agriculture in these high potential areas. The lower potential soils often have capacities to grow tree crops such as rubber, oil palm, cocoa etc.

This special issue of the journal contains about 30 papers from various African countries, providing thus a panorama of insights into the challenges to sustainable soil management in Africa. Some of the papers are general review articles; others are reports on results of specific experiments or surveys. Readers are encouraged to read these papers with an open mind and readiness to appreciate the great diversity of soil resources in this large continent, a situation presenting greater challenges which make the task of the soil scientist more complex but thrilling.

The importance of soil surveys and assessments

The articles acknowledge that detailed soil surveys are expensive and time consuming but are indispensable for sustainable land use. They also indicate that opportunity costs in terms of yield and crop loss if soil survey information is lacking far outweigh the cost of undertaking the surveys. The essays further indicate that Africa has beautiful broad scale agro-ecological zone and soil maps, but that these are not suitable for location-specific cropping and management planning.

In order to undertake detailed soil survey and related work, including research, strong, well manned and equipped soil institutions (which are currently lacking in most countries) are needed. A few papers also make strong pleas for the development of local national soil classification systems, despite existence of major international systems such as the Soil Taxonomy and World Reference Base for soil resources (WRB). The latter are believed to be good for international communication on soils but not effective for local interpretation and decision making on land use and planning or sustainable soil management. A paper from Rwanda highlights the existence of local soil classification systems at community level. Local communities give names to different soils that they distinguish and have effective land suitability evaluation systems based on their soil classification; from experience they know what can be done on which soil. For example, farmers know that different soils need to be fertilized differently.

Soil fertility management

Several papers deal with various aspects of soil fertility management, especially in the highly weathered soils of the humid tropical areas where almost all plant nutrients are contained in the vegetation (ISSS Working Group RB, 1998[2]). Long term slash and burn and fallow practices have contributed to the fertility status of soils in areas where this is practiced. Due to population pressures, fallow periods have drastically reduced, resulting in a non-sustainable system.. An experiment described by a paper from Nigeria shows that when plant material was burned and the ash was left on the soil, or where unburned plant residues were incorporated into the soil, second year yield drop was far less than when plant residues were baled and removed – in which case second year yield dropped by 45%.

Minimising risk, including from climate change

There are various technologies which small scale farmers in Africa use to minimize risks and cope with adverse soil and/or climatic conditions. Examples discussed in the articles include selection of appropriate cultivars that are adapted to specific unfavourable or stress conditions. One paper from Democratic Republic of Congo studied the selection of maize cultivars for genetic traits that confer adaptation to low nitrogen conditions. An inspirational paper from Niger describes the successful implementation of indigenous soil and water techniques at community level. Two papers from Cabo Verde report how the dedication of successive governments to the cause of soil and water conservation has resulted in astonishing increases in yields of fruits and vegetables in this Small Island State.

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Contributors from Mozambique share the experiences of farmers taking steps to reduce their vulnerability, adapt and mitigate or reduce Green House Gases (GHG) emissions and enhance GHG sinks. Farmers decided to abandon rainfed cropping and shifted their whole attention to crop production in the seasonally flooded wetlands along a major river. Such cultivation during non-flood season is practised widely along big rivers in Africa. Abilities of different systems to sequester carbon and minimize greenhouse gas emissions also received attention.

The human factor is key

Human factor in sustainable soil management is of importance as reflected in two articles from Tanzania and one from South Africa. The articles demonstrate the importance of understanding the needs and priorities of farmers and communities and how decisions are taken. Authors demonstrate that it is only by attending to the needs and aspirations of the people that the environment can be saved. This is demonstrated in one case where the conflict between a community and a protected forest area was resolved by establishing an irrigation scheme for the community next to the protected area. In another case it was found that farmers opted not to adopt a conservation agriculture package, but only selected components from the package, with very good reasons. This corresponds with an emerging fact that whereas scientists see a complete recommended package, farmers see the individual components of the package and choose individually. One human factor for success that is key is working together. The African Soil Partnership has ambitious plans to this effect as explained in an article featured under *FAO activities and results* section.

The country under focus in this edition is the Republic of Cabo Verde. A rural development researcher at the National Institute for Agrarian Research and Development (INIDA), Jacques de Pina Tavares, gives us a flavour of how watershed management technologies have been designed to boost the resilience of Cabo Verde to climate change, and to mitigate the effects of desertification.

We believe this special issue of Nature & Faune journal, with its exciting variety of papers dealing with issues related to sustainable soil management in Africa is an important contribution towards promoting sustainability on the continent. As we conclude the 2015 International Year of Soils and begin the 2016 International Year of the Pulses we believe that the Africa region will take on the knowledge generated and awareness raised and consolidate it during the deliberations at the 7th Conference of the African Soil Science Society taking place in Burkina Faso in February 2016; and at an Inter-ministerial Conference to be organized later in 2016 to review progress made on the Abuja Fertilizer Convention - setting a new timeline for implementation and strengthening its implementation from fertilizer focus towards integrated soil fertility management. There is also the 20th session of African Forest and Wildlife Commission in Kenya (February 2016); and the 29th Africa Regional Conference in Côte d'Ivoire (April 2016). These upcoming conferences and high level engagements will build on steps already taken to inspire hope and provide solutions to Africa's development challenges, including the disquieting soil and soil-related challenges. I hope that the African citizenry can count on you to face up to these challenges!

EDITORIAL

Understanding sustainable soil management in Africa

Michiel C. Laker[1]

The 2013 *Soil Atlas of Africa* (Jones, A. *et al* 2013) makes it clear that only approximately 8% of the continent is covered by soils that *"are relatively free of natural constraints for agriculture"*, and that much of the presently cultivated land in Africa *"occurs on areas that are deemed unsuitable . . . while other areas appear suitable but are not cultivated."* The Atlas also reports that *"Africa's climate has made agricultural improvement difficult"*. Many of Africa's soils have limitations for crop production, some very severe, and they require careful management if they are to be used sustainably. The Atlas includes a global soil map, which "clearly shows that Africa has a unique pattern of soils that is not replicated on the other continents" (Jones et al., 2013). A striking feature is the almost complete absence in Africa of the deep, inherently fertile, organic matter rich, friable (and thus easy to cultivate) soils that cover large areas of the temperate countries at high latitudes in the northern hemisphere. These include the Chernozems, Kastanozems and Phaeozems of the American prairies and the Russian steppe. It is difficult to maintain relatively high soil organic matter levels under the high temperatures of Africa. A major proportion of the good soils are black or red clayey soils that are difficult to cultivate. They cannot be successfully managed using technologies and management regimes that are successfully used in the temperate countries without making appropriate adaptations to these. In many cases completely new approaches are required to enhance soil fertility, productivity and sustainability.

Soil scientists in Africa are thus faced with three major challenges, namely (i) to ensure that all areas covered by good soils are utilized to their full potential, (ii) to find appropriate adaptations to existing technologies to improve soil management and production and (iii) to develop new technologies for sustainable management – especially of the extensive areas of marginal soil that farmers are obliged to crop to achieve food security and adequate nutrition in Africa.

African farmers also face a range of political, socio-economic and socio-cultural constraints. Poor infrastructure in terms of roads and transport services is a major factor, limiting access to inputs and delivering of produce to markets, especially for small scale commercial farmers in remote rural areas. Often the required inputs are not available in an area, or even in a country. Where it is available, the input, e.g. fertilizer, is often extremely expensive. Advisory services are often limited – both in accessibility and in relevance to the small farmers. Where modern technologies are introduced there is usually inadequate technical backup, both in terms of mechanics/technicians and availability and affordability of spare parts. These include anything from tractors and harvesters to irrigation pumps and systems. The more sophisticated a technology is, the higher are its requirements in terms of physical infrastructure and maintenance services.

These constraints call for approaches and strategies adapted to the conditions under which farmers have to operate. In most areas of Africa local farmers have themselves developed appropriate approaches and technologies that are adapted to the challenges confronting them. Rural farmers have over the years used indigenous knowledge such as mulching, intercropping, simple erosion control measures, etc. to maintain and improve soil quality and yields. The Land Care programme in South Africa developed what it believed to be the best practice for small farmers to grow maize: in a field trial leader farmers had to compare this best practice with their own practice in order to prove to farmers in the area how much they could improve their maize production by adopting the best practice. The outcome was a big surprise: By far the best yield was obtained by Leader Farmer 4 with his own practice that he had developed (Figure 1). This is a good example of where it would be the best approach to start with the technology of Leader Farmer 4 and from there to improve the farmer's existing approach and transfer that to other farmers. It is certain that there are many similar examples from other countries in Africa.

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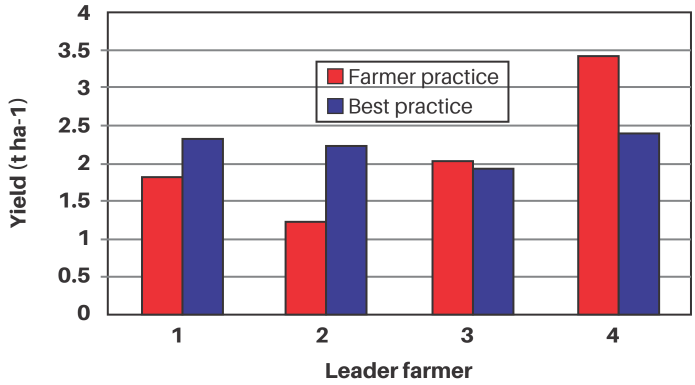

Figure 1. *Maize yields in farmer-led trials: Magusheni, Eastern Cape, South Africa*

Good crop yields cannot be attained on a sustainable basis without good soil classification and especially correct land suitability evaluation. In the past few decades there has been an explosion of interest in the numerous local indigenous soil classification and land evaluation systems of population groups and communities throughout Africa. Most important is the growing realization of the value of these by scientists.

Farmers and soil scientists are key people to be involved in any drive towards sustainable soil management. Farmers have their accumulated knowledge of what can be done successfully with soils on a given landscape (mountain slope, dryland, wetlands, coastal strips etc.) and are cognizant that soil suitability depends on what the farmer wants to grow there. Even desert sands can grow a lot of food and forestry and horticulture can thrive very well in some of the soils described in general terms as infertile. Soil scientists have the basic scientific knowledge required to forecast what will happen when a new or adapted land use or management system is introduced. Success can, however, not be achieved without the involvement of and effective close interaction with others, like agronomists, horticultural scientists, engineers, extension officers, etc. In many cases effective interaction with decision makers and politicians is also essential. Unfortunately farmers are usually not involved in decision-making on agricultural development. Likewise soil scientists are often not involved or their advice and recommendations ignored or rejected in decision-making processes. The outcome too often leads to project failure, soil degradation and negative impacts on farmers and their families. Peter Ehrlich, population geneticist from Stanford University once stated that soil is the most neglected resource on earth. Experiences of soil scientists worldwide and my own experiences, especially when it comes to small farmer development, are that soil scientists are probably the most ignored scientists in the world (Laker, 2000). So, in this International Year of Soils the focus should not only be on the soils of Africa, but also on the soil scientists of Africa and the farmers they work with.

In marginal or non-deal soil and climatic conditions, selection of appropriate crops and especially adapted cultivars is critically important for success. Small-scale farmers in Africa have over centuries consciously developed cultivars that are highly adapted to their conditions by each year collecting seed from plants that gave the best yields. Introduction of so-called high yielding varieties that are bred for top performance under ideal conditions fails when they are introduced in marginal areas, performing worse than the local cultivars. By tapping into the extremely valuable gene pools of which the small scale farmers have been the custodians for centuries plant geneticists/breeders could develop ranges of more productive cultivars that are adapted to different non-ideal situations.

My own experience highlighted the importance of first listening to farmers. My contact with indigenous small-scale agriculture started on the hills of **East Pondoland** in the far northeastern corner of the present Eastern Cape province of the Republic of South Africa during my June university holidays in 1960. The area has good rainfall (700 to 1 000 mm per annum) and soils that are physically good, but are acidic and have very low phosphorus content. Somehow one farmer discovered that I was an agricultural student and came to ask for advice on how he could grow his maize better. Firstly, I became aware that here was someone who really wanted to improve his crop production. Secondly, I realized that, despite my university knowledge and practical experience of agriculture on my uncle's farm since childhood, I did not actually have answers to his questions. I could, for example, not advise him to apply fertilizers, because there was nowhere that he could get fertilizers and no means to get it to his area over the very bad roads with almost no motor transport. Manure could be an option, but that was scarce, being in demand for many other essential purposes in and around the homes. Although I could not give him clear advice, we had a number of intensive discussions on agriculture. Somehow something good must have come from these for him, because a few years later I received a Christmas present from him through the mail thanking me for the helpful conversation.

My big lesson from then on was that one must never go with "clever" preconceived ideas into any farming community. First talk with the farmers. **Listen to them**. Do not "lecture" them.

Make observations. *"Good observation is good science and can be more useful than statistically planned experiments."* (Julian Thomas, 2012) Then form a picture and try to develop suggestions **together** with the farmer(s). Later on I learned a lot from amazing observations by farmers themselves and technologies used by them. I would like to share a few experiences.

Much later in my career (in 1995) I participated in a study tour of indigenous soil and water conservation practices in **Burkina Faso** and **Niger**. On the first day of field visit I became frustrated by what we were told by our field host from Europe. The area had planting pits and after making my own observations, I asked him that evening: *"Did you see that they plant the crops on the mounds of soil next to the pits and not in the pits?"* His reply was: *"That is nonsense. They plant in the pits and not next to it, because the water collects in the pits."* The next day we were taken to a community which was described beforehand as very progressive. From our bus to the meeting place we passed a field in which the crop was planted on the mounds and not in the pits. I pointed it out to him and requested that he ask them why they plant on the mounds and not in the pits. When he did that, the spokesperson for the community gave a long reply in French, which the host then translated as: *"If it is a shallow soil we plant on the mound. If it is a deep soil we plant in the pit. If it is a soil that is not crusting (sealing) we do not make pits."* These clever adaptations by farmers of a technology to specific situations all made perfect scientific sense.

A striking feature of the successful soil and water conservation strategy in Burkina Faso was that it was completely community based. Decisions were made by individual communities. Government did not dictate what had to be done and how it had to be done, but was available in the background for advice and support as and when requested by a community. It is very important to provide advice and support on this basis.

In some Southern African countries ox-drawn rippers (chisel ploughs) have been used for a long time, using well-planned strategies. In the traditional Xhosa area of South Africa in the northeast of the Eastern Cape province, between the Kei river in the south and the border with KwaZulu-Natal province in the north, it was used in what the local people call the *Gelesha* system. In this system the soil is ripped in the middle of winter, just after harvesting maize or sorghum. This opens up the soil surface for effective infiltration of the significant amounts of rain in spring which it is important to capture effectively in the soil because the area is characterized by the mid-summer droughts which are common along the eastern seaboard of Africa. Furthermore, the oxen are still in a good condition in middle winter, but by the end of winter they are generally in a poor condition and would not have the strength to pull the ripper through the hard dry soil. Unfortunately the system largely disappeared after introduction of government subsidized tractor ploughing systems. The mechanized system did not follow the *Gelesha* approach in terms of timing of cultivation and type of implement used, resulting in poor water conservation (capturing of spring rains) and serious soil physical degradation like crusting and compaction.

A study in **Zambia** found that individual small-scale farmers produced excellent crops on the fertile soils along the banks of the Zambezi river (Plate 1), but they had to severely restrict their production, because the local market was very small (Kwaw-Mensah, 1996). They actually introduced a quota system between themselves so that everyone could get some share of the market. There was a big market in Lusaka, but due to poor roads and transport services they could not get their produce to that market. Further north along the Zambezi production suddenly expanded when a big supermarket group opened in the copper belt and sent in their trucks to collect vegetables directly from the farms (Daka, 2001). With the expansion traditional bucket irrigation became too cumbersome and alternative irrigation systems had to be found. In the end two systems that were both well-known elsewhere in Africa were introduced. The first was the treadle pump (human foot operated pump). The farmers initially rejected it, but when it was redesigned according to the wishes of the farmers and the construction materials modified so that artisans in the villages could build and maintain the pumps, 2 500 pumps were adopted within three years. The second was clay pot irrigation. In field experiments it was found that with clay pot irrigation a variety of vegetable crops could be grown with only 30 to 50% of the water that was used with the traditional local system.

Plate 1 – *Crop production by a small scale commercial farmer on the banks of the Zambezi River in Zambia. (Also note the tomato "trees" on the right and at the back.)*

Farmers in Africa generally have a good idea of what to do and how to do it on different soils in different areas, considering the different types of constraints within which they have to operate. I believe that they would like to improve their farming, provided that it is done in a sensible way. I believe that this should form the basis from which to systematically improve skills and yields in such ways that agricultural, economic and environmental sustainability is achieved. High-tech farming depends heavily on the availability of both excellent physical infrastructure and support services in terms of spare parts, technicians/ mechanics, agricultural inputs, advisory services, etc. Where these are not available, it fails.

Scientists and governments have to understand each situation and its limitations correctly and act accordingly. Agriculture has two primary components, namely the farm and the farmer. "Agricultural development deals not only with increased food production, but includes parallel changes in an entire way of life. Much of the research has either missed this point entirely, or has not reached it yet … The processes of meaningful change are slow, but must be honoured if such change is done in the best interest of the beneficiary." (Barbara Rosenthal in an MSc seminar at Cornell University, 1977). Change is urgently required in Africa, but it must be managed with adequate consideration of indigenous soil knowledge by local resident populations such that its outcome is constructive.

Africa is a unique continent with unique challenges in regard to its soil and climatic resources. The high spatial variabilities in the qualities of soils and the nature of their limitations in Africa require site-specific solutions. Blanket solutions do not work (IFAD, 1992). Africa has a very valuable resource in the vast pool of accumulated knowledge amongst its farmers. By tapping into this and blending it with the scientific knowledge of its soil scientists and others a route could be plotted for improving agricultural productivity on the continent by means of appropriate sustainable soil management approaches and strategies. Maybe we should adopt the slogan which I saw on the wall of the office of Bob Reginato at the US Water Conservation Laboratory in Phoenix, Arizona: "We are facing a series of great opportunities, brilliantly disguised as unsolvable problems."

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Thomas, J. 2012. Unpublished report to M.C. Laker on research experiences at the Makhathini research station, South Africa. FAO, Rome. (Note: The Makhathini research station was established for the purpose of conducting agronomic research with a view to the development of an irrigation scheme for small scale commercial farmers.)

Tailoring soil fertility management inputs to specific soil types: case study of a pot experiment in Rwanda

Pascal N. Rushemuka[1] and Laurent Bock[2]

Summary

Promoting intensive use of fertilizers to boost productivity of the inherently poor soils of Rwanda requires careful understanding of crop responses to their application. Using a multi-scale and nested hierarchy land system reasoning, composite sub-surface soil samples from four representative soil types were considered to demonstrate the obligation to understand the soil spatial distribution at watershed level as a means of guiding the application of appropriate soil fertility management inputs to specific soil types. Lime/travertine rock, cattle manure/ farmyard manure (FYM), fertilizers and their different combinations were tested to four soil types. Results confirmed significant different responses between soil types and soil fertility management input treatments ($p \leq 0.001$). It was observed that for Urusenyi (Entisols), the application of FYM has the ability to improve the fertilizer response. However, because of the good yield of the control, the intensive use of FYM can be a recommendable option. For Inombe, all the treatments where NPK was included gave definite yield increases, which is significantly higher than the treatments where NPK was not included. In this soil type the recommendable treatment was the combination of manure and fertilizers. For Umuyugu/Mugugu (Oxisols) and Nyiramugengeri (Histosols), the response in all treatments without lime was insignificant. In contrast, the effect of lime was spectacular and significant vis-à-vis to the non-limed treatments. In these two soil types, the best treatment was the combination of lime, FYM and fertilizers. This experiment confirmed the idea of tailoring soil fertility management inputs to specific soil types at watershed level.

1 Introduction

The Rwanda national territory is divided into different Agro-Ecological Zones (AEZs) at a scale of 1:250,000 (Delepierre, 1974). However, due to complex relief and parent materials, there remains important soil variability within each AEZ (Steiner, 1998). Rwanda has also a national comprehensive soil map (Birasa et al., 1990) at a more detailed scale (1:50,000). This soil map is known as CPR (for Carte Pédologique du Rwanda). Still, due to a number of reasons (Rushemuka et al., 2014a, b, c), this soil map does not help to totally overcome the problem of soil type variations over short distance within one AEZ (Steiner, 1998). In addition, in the complex biophysical environment of Rwanda, it might be unrealistic to propose a more detailed soil map as this would imply prohibitive cost without really being able to solve the core problem. On the other hand, it has been observed that farmers in Rwanda (Habarurema and Steiner, 1997; Steiner, 1998; Rushemuka et al., 2014) like many others worldwide (WinklerPrins, 1999; Barrera-Bassols and Zink, 2003; Barrera-Bassols and Zink, 2006; Barrios et al., 2011) have a precise and accurate mental soil map with a very accessible soil nomenclature. At the same time it has been observed that without systematic consideration of different soil types at watershed level, soil scientists in Rwanda have been unable to determine soil-specific fertilizer recommendations for the main crops of the country after now more than 50 years of soil fertility management research (Rushemuka, 2014a). In these circumstances only generic/blanket/blended recommendations are formulated to the entire national territory without any consideration to the diverse AEZs and soil types. Therefore, farmers lack the precise recommendations for their specific soil types (Steiner 1998). This situation makes interventions like crop response to fertilizers more erratic and less profitable (Rutunga, 1991; Sanchez et al. 1997), hence the low adoption of promoted fertilizer technologies (Steiner, 1998). Therefore the question is posed as why scientists should continue to fail/ignore/overlook to integrate scientific and farmers' soil knowledge and build soil fertility management strategy and draft extension messages on the farmers' accessible soil nomenclature system? This study tested the crop response to the application of lime, manure, fertilizers and their different combinations. The objective was to demonstrate that different soil types occurring in different land units of the same watershed may need different soil fertility management recommendations. The overall idea is that, at watershed level, the soil type is the fundamental soil fertility management unit and that the integration of the farmers' and scientific soil names may help to make the soil fertility management extension messages clearer and more accessible and rational. Therefore, this study is not only a traditional pot experiment but more importantly a practical example of how farmers' and scientific soil knowledge can be integrated to solve practical land-related problems as recommended by WinklerPrins (1999).

2 Materials and methods

2.1. Soil sampling

Composite soil sampling was done, taking into account land units, CPR soil mapping units (Birasa et al., 1990) and farmers' soil nomenclature. Four farmers' soil types were considered in four land units along the slope (Table 1). Soil samples were taken at 25 cm depth with the help of an auger. Each composite soil sample was a mixture of 10 composite samples taken in 10 farmer's fields of 0.5 ha (on average) for each soil type under the same land use. Laboratory analysis of

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composite soil samples, which involved different soil properties: particle size, soil pH (water and KCl), total organic carbon, total nitrogen and exchangeable bases, was conducted in the laboratory at the 'Centre Provincial de l'Agriculture et de la Ruralité' in Belgium. Results are presented in Table 2.

Table 1 . Soil type according to farmer and scientific soil knowledge in relation to the land units

Soil number	Land unit	Soil description		
		Farmers' Soil Types	Connotation	Scientific (family) Soil Taxonomy (1975) after CPR [Carte Pédologique du Rwanda soil map]
Soil 1	Interfluves	Urusenyi	Gravely soils	Loamy-skeletal, mixed, non-acid, isothermic lithic Troportents
Soil 2	Shoulder	Inombe	Sticky soils	Clayey, kaolinitic, isothermic, humoxic Sombrihumult
Soil 3	Back slope	Umuyugu	Friable soils	Clayey, kaolinitic isothermic Sombrihumox
Soil 4	Valley	N.mugengeri	Tissue soils	Euic, i sohyperthermic typic Troposaprits

Table 2 . Texture and chemical properties of A horizon

Soil No	Gr	Cl	Si	Sa	pH Wa	pH KCl	ΔpH	OC	TN	C/N	Ca	Mg	K	CEC
	(%)							%			Cmol/kg			
1	37	27	17	56	5.7	4.9	0.8	2.3	0.2	11	5.4	0.99	0.3	6.9
2	7	34	16	49	6.0	4.9	1.1	1.4	0.1	9	3.8	1.89	0.1	7.1
3	0	46	13	42	4.5	4.1	0.4	2.6	0.2	12	0.5	0.16	0.1	3.7
4	3	32	26	43	4.3	4	0.3	10	0.2	15	0.5	0.08	0.1	3.8

Gr = gravel; Cl = Clay; Si = Silt; Sa = Sand; Wa = Water; ΔpH = pH (Water) – pH (KCl) OC = Total Organic Carbon; TN = Total Nitrogen; CEC = Cation Exchange Capacity

2.2 Matching soil types and appropriate inputs

A pot experiment was conducted from May 2011 to August 2011 to demonstrate the need to tailor soil fertility management to specific soil types. The experiment was conducted at Mamba hill in the greenhouse of the Faculty of Agriculture of the National University of Rwanda (NUR). The test plant was the Sorghum *bicolor (L.) Moench,* variety IS 21219, from ICRISAT.

- *Experiment layout and treatments*

  The trial was a factorial Randomized Complete Block Design (RCBD) three times replicated. Two factors were considered: soil type (S) with four levels and fertilizer type (F) comprising eight treatments, giving a total of 96 pots. Different treatments were defined to test different hypotheses.

  F1. Control or zero input: the reference treatment; to test the soil type's natural fertility potential.

  F2. Lime/travertine; to test the need for liming in the acid soils of Rwanda.

  F3. Farmyard Manure (FYM): to test response to FYM; traditional farmers' soil fertility management practice.

  F4. NPK: to test the response to inorganic fertilizer as new input being widely promoted.

  F5. Lime + FYM: to assess the opportunity of introducing lime in farms where manure gave poor results.

  F6. Lime/travertine + NPK: to evaluate the effect of lime production where fertilizers gave poor results.

  F7. NPK + FYM: to test the interaction between FYM and fertilizer as a sustainable solution.

  F8. Lime + FYM+ NPK: to test the interaction between lime, FYM and fertilizer for the extremely acid and depleted soils.

- *Input application and trial set up*

  Double polyethylene pots 4 cm deep and 16 cm wide were used to contain soils and drainage water. Each soil substrate was put into a set of two pots one containing another. In the inner pot containing the soil substrate, four little holes were made in the bottom to allow the drainage of excess water. The role of the outer pot was to collect water draining from the soil in order to return it to the soil in the inner pot to avoid nutrient loss. in each pot soil was homogeneously mixed with amendments according to treatments.

The following inputs rates were used:

- 1 kg of soil/pot
- 0.15 g of NPK per pot: equivalent of (51 kg of N, 51 kg of K_2O, 51 kg of P_2O_5)/ha or 300 kg of NPK 17-17-17 ha^{-1}, the blanket recommendation used for sorghum in Rwanda.
- 5 g of FYM per pot: equivalent of 10 t/ha, the general recommendation in the area.
- 4.2 g per pot of lime (Mashuza travertine: 40% of CaO.): equivalent of 8 t/ha of travertine.

Input dose per kg was calculated assuming 2,000,000 kg of soil/ha on a basis of a soil depth of 15 cm and 1.3 soil density (Brady and Weil, 2002).

Ten seeds were planted per pot. After germination these were thinned to seven per pot. The pots in each block were rotated every day to ensure even distribution of light and avoid biased results..

- **Trial management and data recording**
  Watering of the pots was done on a regular basis every two days. The water rates were calculated considering the soil water retention capacity previously determined. Every day of watering, the drainage water collected in the outer pot was recycled into the soil. Sorghum biomass yields were harvested three times at 28 day intervals after planting. Fresh weight of the plants (g) was recorded and the means for the three cuts was calculated.

- **Data analysis**
  Statistical analysis was performed using the GenStat software, (12th editions). Differences in various treatments were tested using "two-ways analysis of variance (ANOVA2) in Randomized complete Block design, with least significant mean differences at 5% probability level. The mean yield separation was done using Duncan test.

3. Results and discussion

Our results showed significant differences between soil types and treatments and the absence of interaction between soil types and treatments ($p < 0.001$) (Fig1).

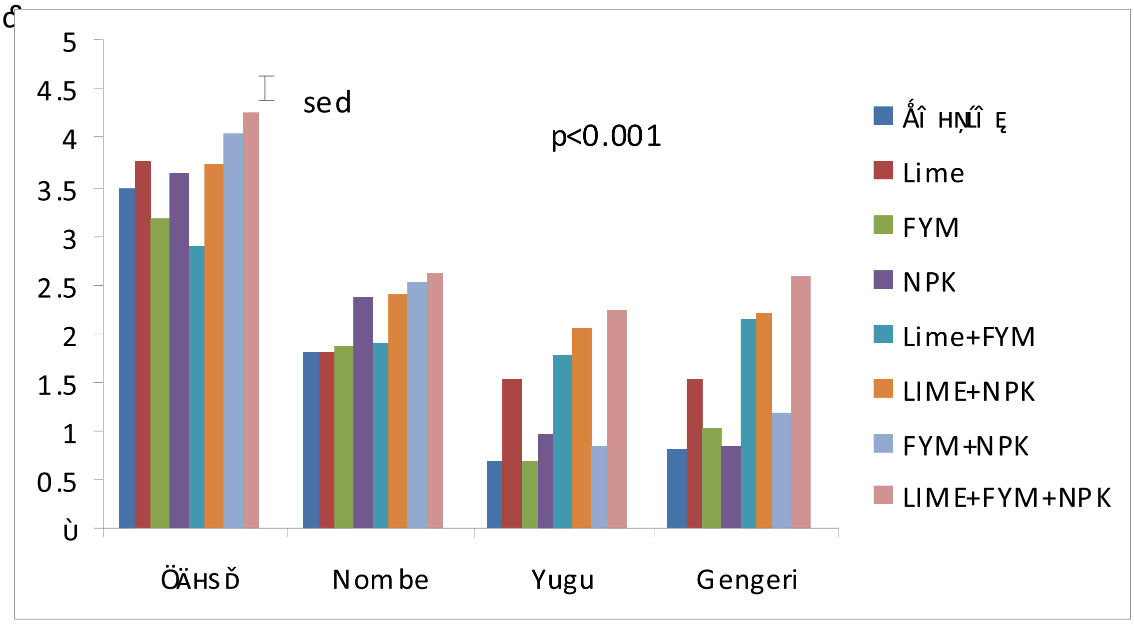

***Figure 1** Mean sorghum biomass yields expressed in grams per pot of 1 kg of soil (g/pot) of three cuts: crop response to the soil type and soil fertility replenishment treatments. In this figure Senyi= Urusenyi; Nombe= Inombe; Yugu= Umuyugu; Gengeri= Nyiramugengeri. Sed=standard error deviation.*

The mean separation showed that the different soil types could be grouped into three fertility categories (Table 3). In this table it is shown that *Urusenyi* is the most productive and that *Inombe* is the second while the *Umuyugu* and *Nyiramugengeri* are the least productive. This is explained by their respective chemical soil properties such as pH, Ca and Mg (Table 2). This is consistent with farmers' perceptions (Rushemuka et al., 2014a). The implication is that farmers know that they need different soil fertility management strategies and that they know the differences between their soils. But understanding different soil types and taking into their spatial distribution during the implementation of soil fertility management strategies is a big challenge for decision makers, scientists and extensionnists in agronomic sciences (e.g. soil fertility management and crop selection and breeding) mainly because of poor links between pedology (soil map) and agronomists (Steiner, 1998; Rushemuka et al., 2014b). There is also a lack of understanding and appreciation of the valuable indigenous knowledge of local farmers. As a consequence decision makers in policy and practice typically use insufficiently the research-based and farmers' knowledge available and researchers typically produce insufficiently knowledge that is directly usable (Wiechselgartner and Kasperson, 2010). This would imply that the communication gap between pedologists and agronomists on the one hand and between scientists and extensionists and farmers on the other hand should be filled (Rushemuka et al., 2014b).

Table 3. Mean yield separation of different soil types

Soil Type	*Average sorghum biomass [yield grams per pot of 1 kg of soil (g/potl)]*
Urusenyi	*4.10a*
Inombe	*2.49b*
Umuyugugu	*1.76c*
Nyiramugengeri	*1.97c*
Prob	*<.001*
SED	*0.078*

The statistic test also showed that different treatments produced significantly different effects in each soil type (Table 4). For *Urusenyi,* the Control has a good biomass yield in the same mean separation category with many proposed treatments (Table 4). This is consistent with the good properties of this soil (Table 2). Striking however could be the fact that treatments with FYM (F3) and FYM + NPK (F6) showed inferior biomass yield compared to control (F1) and lime alone (F2). The difference between the Control and the FYM is even significant. The explanation could be an external fact: indeed after the first cut where these treatments (F3) and (F6) had got higher biomass yields compared to the control (data not shown) a certain fungal population (probably due to FYM mineralization) was observed in these treatments which reduced the yield after the first cut. Lime (F2), NPK (F4) and Lime + NPK (F6) gave identical results, a bit higher than the control, but these increases are not statistically significant (Table 4). All three are significantly higher than Lime + FYM (F5). Interesting is that whereas FYM (F3) and especially Lime + FYM (F5) gave negative results, in contrast when FYM was applied together with NPK, i.e. FYM +NPK 5 (F7) and Lime + FYM + NPK (F8), FYM actually somewhat boosted the positive reaction from NPK. In this combination FYM is expected to have raised the soil CEC thereby improving fertilizer use efficiency in these soils of small CEC (Table 2). The soil pH and Ca and Mg levels were already good (Table 2).

For *Inombe* neither lime nor FYM treatments: Lime (F2), FYM (F3) and Lime + FYM (F5) gave any response, neither negative nor positive. This is normal because the soil pH and Carbon content could not suggest big response of these inputs (Table 2). In contrast all the treatments where NPK was included, alone or in combination with lime and/or FYM (F4, F6, F7, F8), gave definite yield increases, which are significantly higher than the treatments where NPK was not included (Table 4). This could be explained by the low saturation of the complex of this soil type. The F7 results suggest that *Inombe* soil type requires the combination of manure + fertilizers for its optimum production. In this combination FYM is expected to increase the CEC while the fertilizers are expected to saturate the soil complex. The results from this experiment on this soil type are consistent with Rutunga and Neel (2006) who observed that lime is needed in soils with pH <5.5.

For the extremely acid (pH<5) and depleted *Umuyugu* soil (Table 2) only treatments where lime was included: Lime (F2), Lime + FYM (F5), Lime + NPK (F6) and Lime + FYM + NPK (F8), gave definite positive responses that are significantly higher than the control (F1) and all the non-lime treatments: FYM (F3), NPK (F4) and FYM + NPK (F7) (Table 4). The treatments without lime gave basically no response, neither positive nor negative. The same situation was observed by Rutunga and Neel (2006). The response with Lime (F2) alone was smaller than where FYM and/or NPK were applied together with the lime. The differences between Lime + FYM (F5) and Lime (F2) and Lime + NPK (F6) were not significant (Table 4) but the difference between Lime + FYM + NPK (F8) and Lime (F2) was highly significant. These results clearly indicate the importance of liming, but that lime alone does not give good yields, it has to be accompanied by manuring and fertilization. The recommendation for this soil type is the combination Lime + FYM + Fertilizers. In this combination, lime is expected to have raised the soil pH to at least 5.5, to supply Ca and Mg as plant nutrients and to have improved the P use efficiency (Rutunga and Neel 2006). The fertilizers are expected to have supplied the N P K nutrients while the FYM is expected to have increased the nutrients by increasing the soil CEC and by supplying additional nutrients. On the other hand, applying fertilizers or manure to such soil just gives absolutely no response without liming. The same situation was reported by Rutunga and Neel (2006).

For the extremely acid and depleted *Nyiramugengeri (*Table 2) soil the treatments where lime was not included also gave very little response, as could be expected after the experience of *Umuyugu* soil. Response from Lime alone (F2) was almost identical to that for the *Umuyugu* soil. In this soil there was an important difference, namely the good response with FYM where it was applied together with lime (F5), as good as for Lime + NPK (F6). Where FYM was applied together with lime and NPK (F8) it also boosted the response clearly above where only lime and NPK (F6) was applied. So, here is a soil where it was definitely beneficial to apply FYM – together with lime and NPK for the same reasons stated for *Umuyugu* soil.

Table 4. Biomass yield mean separation for different treatments in different soil types

	Average sorghum biomass yield [expressed in grams per pot of 1 kg of soil (g/pot)]			
Treatment	S1	S2	S3	S4
F1	3.48abc	1.80a	0.687a	0.821a
F2	3.74abc	1.80a	1.547b	1.369c
F3	3.17ab	1.88a	0.691a	0.903ab
F4	3.65abc	1.898b	0.991a	0.839a
F5	2.88a	2.382a	1.764bc	2.152d
F6	3.72abc	2.406b	2.060bc	2.204d
F7	4.03bc	2.519b	0.834a	1.196bc
F8	4.25c	2.627b	2.222c	2.579e
Prob	0.063	0.002	<.001	<.001
SED	0.389	0.1992	0.249	0.1456

Overall, these results are consistent with previous studies undertaken at field level (Rutunga, 1991) that showed that in Rwanda, some soils (pH> 5.5) can still produce good crop yields with the application of manure, other soils (pH = 5.2-5.5) need the combination of fertilizers + manure while other soils (pH< 5.2) need the combination of lime +manure + fertilizers. They are also in line with Steiner (1998) who observed a soil fertility gradient with the upper soils yielding more than the lower slope. The practical implication is that we need to understand different soil types in terms of their names (scientific and local), their spatial distribution to be relevant to our stakeholders, efficient vis-à-vis the use of limited soil fertility management inputs and to sustainably manage our environment.

4. Conclusion and recommendations

This study has shown that for the four soil types tested for crop response to lime, manure and fertilizers and their different combinations were statistically different and were grouped into three fertility management classes. The *Urusenyi* was the most productive and the *Inombe* was the second while the *Umuyugu* and the *Nyiramugengeri* was in the last category. Results showed also that the proposed treatments were statistically different in each soil type. It has been observed that *Urusenyi* could still produce good crop yields using the FYM. The *Inombe* for its optimum production requires the combination of FYM and fertilizers. The *Umuyugu* and *Nyiramugengeri* require the combination of lime + FYM + fertilizers. Overall, this experimentation confirmed the need of tailoring soil fertility management inputs to specific soil types.

Given the above-demonstrated importance of the farmers' soil knowledge system the practical implications for Rwanda is that it (1) could be described, mapped and bridged with the scientific knowledge system at least at representative watersheds in each Agro-Ecological Zones (2) should be taught at University as a module of the course of pedology (3) should be recognized and adopted as the National Soil Classification System whereas Soil Taxonomy, the language of the CPR (Carte Pédologique du Rwanda), could play the role of one of the correlation systems for scientific communications (4) should be used to set up land-related strategic plans and to communicate extension messages. This could be easier in Rwanda as everybody countrywide speaks the same National Language: the Kinyarwanda.

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The living soils of Africa

Lamourdia Thiombiano[1]

On the occasion of the 2015 International Year of Soils, it is important to revisit the evolution of soils knowledge in Africa and the major features of its development. The celebration of the Year of Soils through this special publication calls for valuing soils as natural resources that deserve greater attention. Soils are living organisms and their functions within the ecosystems and within human societies are essential to survival as providers of nutrients and anchor to the millions of living plants, animals and human beings of the Earth. Soils support many other services ranging from materials for house building to solid base for our roads. Clay which is a fine-grained soil material possesses healing properties, making it a powerful weapon against a large number of human and animal diseases. It is also used in the beauty industries. In this regard the motto of the United Nations 2015 International Year of Soils: "Healthy Soils for a Healthy Life" is befitting.

Soils and lands are part of the African cultural features and concepts; they are embedded in community characteristics, richness and symbols of power. For centuries, land has been the subject of focus in terms of conquest, wealth and/or peace and security. The capacity of a family to feed itself, a community to ensure food for its members, and a village or a Kingdom to build and strengthen its fame and power, were linked to the extent of land and soil fertility it possess. The vastness of fertile lands for agriculture, expanse of wetlands and rivers for fisheries, immensity of rich and diversified forests for timber and wildlife, as well as extensive grazing lands helped to shape the culture and lifestyle of people and communities. In some Sahelo-Sudanian cultures, burning a fire was the first act of sovereignty; the extent of land burnt would be the extent of the primary territory over which the burner would extend his sovereignty.

Encrusted in cultural heritage, soil knowledge that was transmitted from generation to generation was used by communities in assessing the productive capacities of lands targeted for conquest or settlement. Long exposure to the environment gave communities the capacity to judge from soil color, location within the landscape, nature of parental material, texture and other attributes of soils, what to expect in terms of productivity and for what main uses (Thiombiano, 1995).

Soils and land were considered as sacred because of their key role to communities, in providing food, supporting the forest and water resources, agriculture, hunting and fishing, material for building huts and houses, pottery for cooking and crop storage, and in welcoming human beings *in fine* after their life on earth. Throughout history due consideration was given to the way soil should be managed, to maintain its health to the benefit of human beings, to the glory of a community or a Kingdom. Spiritual values as well as packages of traditions and technologies were developed to ensure that soils are used for the best, and that the resources harvested for food was done in a sustainable way. In a number of communities taboos were set up to protect the soils and maintain them in good health.

During the colonial period other types of approaches and methods of soils characterization and classification, soils and land and water management were introduced through modern knowledge systems. For example, in the 1950's the current Democratic Republic of Congo (DRC) hosted one of the World Soil Congresses, the only one so far, to take place in Africa . Soils scientists from all over the world participated in this great event at which the discovery of *Ferralsols* and *Luvisols/ Lixisols* under the dense equatorial forest was among the amazing revelations for a number of soil specialists (ISSS, 1954)

Later on, in the 1960s, the French and Belgian classification, and the American Soil Taxonomy were progressively adopted across the continent, depending on the patterns of colonial influence and the University in which national specialists in the subject matter were trained. Soils then became an object of scientific curiosity and classification, a provider of raw materials for food and industries within and outside the continent. The land and soil's spiritual nature and the taboos that were indeed its protective cover, were challenged within the minds of new generations of African agronomists and land- users, to allow intensive production. The use of chemical inputs increased. Immense areas were deforested and put into agricultural production to feed the people and for export, to grow cash crops and for wildlife. Together with an increasing population and diversified and even sometimes conflicting uses of soils, the negative impact on soils became increasingly pronounced. In modern times, human beings tend to forget that soils are living bodies; that soils can breathe through the many thousands of microorganisms and fauna they host. Modern agriculture and forest harvesting techniques displaced traditional sustainable agricultural methods: the wisdom from the past in managing soils based on justified present-day needs, and the needs of future generations, became scarce. Sustainable indigenous technologies were gradually pushed away.

In the seventies, desertification emerged as a predominant concern for the African continent and the world. It was then, time to rethink about how to revive the wisdom and regain trust in the *spirits* that live in the soils, the wisdom and best practices from the past. An increasing number of conferences were organized all over the world, starting from one in Nairobi focusing on desertification (UN, 1977).

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[2] *Latin expression for "in the end"*

Forest plantations and afforestation programs as well as a number of technologies and improved practices to fight desertification, were generated by research and applied for better soil management (Thiombiano and Tourino, 2007). Several National Soil Bureaus were set up and developed to provide better knowledge on soils through donor funding and support from national budgets. Maps at various scales were produced in relation to the types of soils, their suitability for crops, forests, livestock and aquaculture. Land use Master Plans and soil suitability maps were produced and made available to policy makers and land managers, using modern soil classification methods and information from historical archives.

With an increasing diversity of soil classification systems, there was a need for correlation and harmonization of the complex terminology and divergent languages used by soil specialists. A major step was the development of the World Reference Base for Soil Resources (WRB), by the international soil science community. As a result, in the 1990s overseas WRB scientists became aware of some of the most important soils of Southern Africa, especially during a field workshop in South Africa. Moreover, WRB tools were well accepted and adopted particularly by the World Soil Congress in 1998 in Montpellier, France (IUSS, 1998). Africa significantly contributed to the testing and improvement of the WRB through the successful Post Congress Tour B7. A tour that took more than one hundred of congress participants through West Africa: from the sandy dune soils of Dori town in the Sahel of Burkina Faso, to the marine dune soils of Abidjan in Côte d' Ivoire. During this Tour, many high profile soil science specialists from six continents experienced the sacred linkage between soils and the lives of human beings, in rural and urban areas. Through cultural performances, direct interaction with land-users on farms and in open soil pit areas (which are a source of laterite blocks for building traditional houses), participants acknowledged the vitality of soils and their importance for life. The "communion" between African soil scientists and their fellow specialists from all over the world was amazing to see, when two meters down in soil pits, they could jointly describe and discuss soil horizons and functioning, and potential of these soils for sustainable uses. Moreover, participants highlighted the importance of focusing attention on how modern knowledge such as Information Technology can enable Africa to better capitalize upon its traditional knowledge and even its beliefs that soil and land are more than just things but instead are living "beings".

The recent publication of the Soil Atlas of Africa in 2013 (Dewitte et al., 2013b; Jones et al., 2013a) was another milestone of a worldwide collaboration, which contributed to African soil knowledge sharing. Soil types of the continent, their distribution according to sub regional coverage and their diverse uses, are illustrated in this Atlas aimed at policy makers, soil specialists and the public at large. This Atlas is in a way a marvelous celebration of the African soils.

The celebration of the 2015 International Year of Soils and the World Soil Day which will be celebrated every year, on 5 December, is a great victory for the millions of land users and virtually every human being. It should urge and inspire humanity to take greater care of soils and provide updated and accurate data and information to policy makers and land users. We need to reconnect with the wisdom of the past encrusted in the greetings of an Ethiopian tribe: "*May your soil be fertile*".

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Towards a sustainable soil security in sub-Saharan Africa: some challenges and management options

Akim O. Osunde[1]

Summary

Soil is an important natural resource that has an existential bearing on mankind, directly affecting the quality of life and human survival. In addition to its role in the sustenance of food security, soil also plays an integral in the global environmental sustainability challenges of water security, energy sustainability, climate stability, biodiversity, and ecosystem service delivery. The promotion and improvement of a robust soil system that is capable of adequately playing these roles therefore becomes an imperative. This underpins the concept of soil security. The major challenge to sustainable soil security in many regions of Sub-Saharan Africa (SSA) is extensive land degradation which manifests as rapid deforestation, soil erosion, nutrient depletion and declining soil fertility. One of the most effective management options that are often used to check these hazards and thus engender sustainable soil security, especially in low-input agricultural systems, is the use of nitrogen fixing legumes (NF legumes). The degree to which a particular legume contributes to soil security depends on its type. While the grain legumes provide nitrogen-rich edible seeds, their residues serve as mulch and contribute to organic matter build-up in the soil. The green manure legumes are grown primarily for use as organic manure and weed suppression, while the woody legumes provide multiple services that include the provision of mulch materials, staking materials and green manure; soil erosion control, nutrient recycling. To the extent that these contributions by NF legumes engender soil security and thus enables the soil to play its role in meeting the global environmental sustainability challenges, especially as it affects SSA, it can be deduced that NF legumes offer a potential for the attainment of a secured continent.

Introduction

Soils constitute a finite resource that is reusable as long as they are not degraded to the point where it is not practically possible or economically feasible to reclaim them. Beyond that point they become non-renewable resources. Soils are fundamental to life on earth and are a key enabling resource, central to the creation of a host of goods and services integral to ecosystems and human well-being. They are the reservoir for at least a quarter of global biodiversity, and therefore require the same attention as above-ground biodiversity. A healthy, fertile soil is paramount to agricultural productivity and thus sustainable food security. In addition to its role in the sustenance of food security, soils also play integral roles in the global environmental sustainability challenges of water security, energy sustainability, climate stability, biodiversity, and ecosystem service delivery. The promotion and improvement of a robust soil system that is capable of adequately playing these roles therefore becomes an imperative. This underpins the concept of soil security. This paper introduces the concept of soil security and its interrelationship with the other previously recognized global environmental challenges. It further highlights the challenges to sustainable soil security in Sub-Saharan Africa and discusses the role of nitrogen fixing legumes in the sustainace of soil security. The paper concludes with some recommendations and suggestions.

Soil security and its interrelationship with the six global environmental challenges

The term "Soil Security" is a new concept that has arisen in response to an emerging international concern about the increasingly urgent challenges facing the global soil stock. Soil security thus refers to the maintenance and improvement of the world's soil resources to produce food, fibre and freshwater, contribute to energy and climate sustainability, and maintain the biodiversity and the overall protection of the ecosystem goods and services (Koch *et al.,* 2012, McBratney *et al.,* 2012). Without a secure soil we cannot be sure of secure supplies of food, fibre, clean freshwater or of diversity in the landscape. An insecure soil is short in the potential to act as a sink in the carbon cycle, and cannot provide a core platform for the production of renewable energy sources (McBratney *et al.,* 2014).

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Soil security and the other global environmental challenges (food security, water security, energy security, climate change abatement, biodiversity protection and ecosystem service delivery) are strongly interconnected and inter-related (Figure 1), as they all have similar characteristics and are addressed using a combination of dimensions with a focus on providing services to humanity.

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Figure 1. Soil security is a major contributor to a number of global environmental issues, all of which are inter-related (Source: McBratney *et al.,* 2012).

It is important to highlight the centrality of the soil to human existence, examine its interrelationship with the six previously recognized global environmental challenges and hence the need for its sustainable exploitation and security. A fully functioning soil is therefore central to solving the big issues of food security, biodiversity, climate change abatement and fresh-water regulation. The concept of soil security provides a useful model that links soil with good outcomes in sustainable development as shown in Figure 1. The key aim in securing soil is to maintain and optimize its functionality: its structure and form, its diverse and complex ecosystems of soil biota, its nutrient cycling capacity, its roles as a substrate for growing plants, as a regulator, filter and holder of fresh water, and as a potential mediator of climate change through the sequestration of atmospheric carbon dioxide (Koch *et al.,* 2013). Maintaining the myriad of interactions between these processes is what gives soil its resilience, productivity and efficiency in the delivery of ecosystem services.

The challenge to sustainable soil security in Sub-Saharan Africa

The major challenge to sustainable soil security in many regions of Sub-Saharan Africa (SSA) is extensive land degradation which manifests as rapid deforestation, soil erosion, nutrient depletion and declining soil fertility. The United Nations Convention to Combat Desertification (UNCCD) defines land degradation as a "reduction or loss, in arid, semi-arid, and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest, and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as deforestation, soil erosion and deterioration of the physical, chemical, and biological or economic properties of soil." (WMO, 2005). Simply put, it is a permanent decline in the rate at which land yields products useful to local livelihoods within a reasonable time frame. Sub-Saharan Africa has the highest rate of land degradation as they have fragile soils, localized high population densities, and generally a low-input form of agriculture. It is estimated that losses in productivity of farmland in SSA are in the order of 0.5-1 per cent annually (WMO, 2005), suggesting productivity loss of at least 25 per cent over the last 50 years. According to UNCCD, the consequences of land degradation include undermining of food production, famine, increased social costs, decline in the quantity and quality of fresh water supplies, increased poverty and political instability, reduction in the land's resilience to natural climate variability and decreased soil productivity.

Given the high levels of nutrient depletion and soil degradation in many small holder farming systems in SSA, associated with high economic cost of fertilizers, and the problems of their availability, the need to explore alternative soil management avenues becomes imperative. Nitrogen fixing legumes offer considerable potential in sustaining crop productivity, maintaining the productivity of marginal lands and minimizing erosion in low-input farming systems (Osunde and Bala, 2001).

The role of nitrogen fixing legumes

Nitrogen is the plant nutrient required in the greatest amount for soil productivity and plant growth. Nitrogen fixing legumes through the natural process of biological nitrogen fixation (BNF) in symbioses with root nodule bacteria (rhizobia) can play a critical role in the achievement of cost effective, attractive and ecologically sound means of reducing external N inputs and improving the quality of soil resources and ensuring the sustainability of soil security.

Worldwide, NF legumes have been reported to fix over 80 million tons of nitrogen annually (Giller, 2001). The amount of nitrogen fixed varies widely depending on the host NF legume plant, the rhizobium efficiency, and the soil and climatic condition of the environment. In addition to their N-fixing capacity, legumes are extremely important in human and animal diets. Globally, they supply about 33% of human protein. Apart from the contribution of part of N fixed for the maintenance of soil fertility, other rotational beneficial effects of NF grain legumes to a succeeding crop include reduction of disease incidence and/or weed infestation. The NF green manure legumes are also commonly used as cover crops to protect the soil from erosion by maintaining a dense canopy over the surface of the soil, and are thus mostly useful as cover crops on steeply sloping lands and for the control of pernicious weeds (Giller, 2001). The NF trees and shrubs provide multiple services to the farmer in the form of agricultural benefits (plant stakes, mulch materials, green manure, animal fodder etc), environmental benefits (shade, soil erosion control, nutrient recycling) and socioeconomic benefits (fruits, vegetables, nuts, building materials etc) (Kang *et al.,* 1990).

Concluding recommendations and suggestions

In conclusion, I wish to make the following recommendations and suggestions on ways to mitigate the challenges of soil degradation and thus ensuring a secure soil in Sub-Saharan Africa.

The resilience of most soils in SSA is inherently low hence the high level of degradation upon cultivation. The lack of a body charged with the supervision of the use, management and treatment of soils and the coordination of projects and researches on soils in most of the SSA countries has degenerated into progressive abuse of the soil through indiscriminate deforestation, bush burning, grazing, land clearing etc. This must not be allowed to continue.

1. The establishment of a well-structured National Institute of Soil Research in each of the SSA countries, charged amongst others with compiling research information on the capability of soils for different crops, developing guidelines for soil conservation and management in the different agro ecological zones of SSA, carrying out basic research that would generate baseline data applicable at the farmer's level is imperative and desirable. The establishment of such Institutes will go a long way in arresting the deteriorating situation of incessant soil abuse.

2. Governments across the SSA countries must make conscious efforts to strengthen the extension services to adequately disseminate information at farm gate on soil suitability, soil conservation strategies and other soil management technologies for sustainable soil security and food production

3. Governments across these countries should embark on building a critical mass of educated farmers using the students in agriculture in the tertiary institutions as the focal point. It is a well known fact that the educated farmer would easily understand and accept information that emanate from research and development concerning the various technology options which could overcome land degradation. Thus conscious efforts should be made to encourage the study of Agriculture and Soil Science in particular through special concessions such as scholarships, bursaries or fees subsidy.

The mitigation of soil degradation and the maintenance of a secure soil should however not be left to governments alone. Each and every one has the responsibility of ensuring the sustainability of our soil not only through our actions but also by helping to disseminate information to others. In line with the foregoing, it is hereby suggested that individually and collectively we must ensure that we

- Replenish whatever we take away from the soil
- Keep the soil always vegetated rather than leaving it bare
- Avoid bush burning
- Plant at least two trees for every one cut down
- Integrate NF-legumes (grains, green manure and woody ones) into existing cropping systems

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Priorities for Sustainable Soil Management in Nigeria

Victor Okechukwu Chude[1] and Azubuike Chidowe Odunze[2]

Summary

Planning and executing sound natural resource management at watershed and landscape levels has become increasingly important for retaining ecological integrity and ensuring that food and fibre systems are resilient enough to absorb shocks, stresses and avoid land and water resources degradation. Prioritizing and addressing desertification, land degradation and climate change challenges in Nigeria is critical for achieving food security and nutrition, their adaptation to climate change, protection of biodiversity, development of resilience of soil to natural disasters to benefit from new scientific knowledge detailing extent and importance of ecosystem services and their roles in sustaining human and agro-ecosystems. In Nigeria and for agricultural purposes, sustainable land management which combines technologies, policies and activities aimed at integrating socioeconomic principles with environmental concerns is advocated. Prioritizing sustainable soil management in Nigeria requires that land/soil degradation; a common sight in Nigeria that continues unabated due to absence of a 'National Soil Research Institute' with the mandate to oversee use, sustainable management of the nations' nonrenewable natural resource (soil) and monitoring incidence; if any, of land degradation across the country be established. Also, most productive agricultural lands are rapidly impoverished due to nutrient mining by crops, soil erosion and improper soil management practices. Integrated soil health/quality management approaches should be prioritized and adopted to ensure sustainable agricultural productivity, food security and environmental conservation. Detailed soil map of Nigeria focusing on potential agricultural productive areas should be conducted to allow for planned sustainable intensification of agricultural production and the attainment of national food security

Introduction

Planning and execution of sound natural resource management at watershed and landscape levels has become increasingly important for retaining ecological integrity and ensuring that food and fibre systems are resilient enough to absorb shocks and stresses and avoid land and water resources degradation (FRP, 2005; IBRD/World Bank, 2006). Prioritizing and addressing desertification, land degradation and climate change challenges will be critical for achieving food security and nutrition, their adaptation to climate change, protection of biodiversity and development of resilience of soil to natural disasters to benefit from new scientific knowledge detailing extent and importance of ecosystem services and their roles in sustaining human and agro-ecosystems. Therefore, investments in emerging scientific knowledge will be necessary in:

- Planning, prioritizing and deployment of appropriate soil management tools for intensive and sustainable soil productivity.
- Improving access to existing knowledge and information on sustainable land management (SLM) and consequences of inappropriate management.
- Rehabilitating land that had been degraded for both productive and ecosystem functions (IBRD/World Bank, 2006).

In this discussion, priorities for sustainable soil management in Nigeria will address the following knowledge acquisition and deployment:

1. Nature and potentials of Nigerian soils for sustainable agricultural production.
2. Needs and priorities for sustainable soil management
3. Institutional settings for sustainable soil management.

Discussion

Nature and potentials of Nigerian soils for sustainable agricultural production

The major soils of Nigeria according to the World Reference Base for Soil Resources (WRB, 2014) are: fluvisols, regosols, gleysols, acrisols, ferrasols, alisols, lixisols, cambisols, luvisols, nitisols, arenosols and vertisols that vary in their productivity ratings and suitabilities for different crops and inherent limitations.

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Table 1: Productivity Potentials of Nigerian Soils

Soil Productivity rating	WRB Major Soil Groups	Area	
		km^2	% of total area
High (1)		-	-
Good (2)	Fluvisol, Gleysols, Regosols	50.4	5.52
Medium (3)	Lixisols, Cambisols, Luvisols, Nitisols	423.6	46.45
Low (4)	Acrisols, Ferrasols, Alisols, Vertisols	289.2	31.72
Low (5)	Arenosols	148.8	16.32

Most soils (Table 1) in Nigeria are cultivable during rainy seasons because of their adequate depths and permeability. However fluvisols, gleysols, regosols, luvisols lixisols, cambisols, nitisols dominate soils of Nigeria with a total land area of 474 km^2 or 51.97% of the total land area and therefore present most cultivable soils in Nigeria as belonging to the medium to good productivity class. Table 2 presents brief comments on use and management of soils in Table 1; hence, their potentials for agricultural use in Nigeria.

Small dams and barriers dug into the earth to prevent soil degradation and to keep rain water on site. A great example of successful sustainable land management practices.

Photo Credit: @FAO/Giulio Napolitano

Table 2: Use and Management of WRB Soil Groups

World Reference Base Soil Group	Use and Management
Fluvisols	Have good natural fertility and attractive agriculturally productive sites on river levees and higher parts in marine landscapes. Paddy rice cultivation is widespread on tropical Fluvisols with satisfactory irrigation.
Gleysols	When adequately drained it can be used for arable cropping, dairy farming and horticulture. Liming of drained Gleysols that are high in organic matter and/or of low pH value enhances the rate of decomposition of soil organic matter, supply of plant nutrients and improved soil quality.
Regosols	In desert areas they have minimal agricultural significance. With rainfall of 500 – 1000 mm/year they need irrigation for satisfactory crop production. Their low moisture holding capacity calls for frequent applications of irrigation water to solve the problem but is rarely economic.
Lixisols	Areas still under savannah or open woodland vegetation are widely used for low volume grazing. Tillage and erosion control measures; such as terracing, contour ploughing, mulching and use of cover crops help to conserve the soil. The low absolute plant nutrients and cation retention makes recurrent inputs of fertilizers a precondition for continuous cultivation
Cambisols	Generally good agricultural land used intensively. In the humid tropics, they are typically poor in nutrients but are still richer than associated Acrisols or Ferralsols, and have greater CEC. Cambisols with groundwater influence in alluvial plains are highly productive
Luvisols	Most Luvisols are fertile and suitable for a wide range of agricultural uses. Luvisols with a high silt content are susceptible to structure deterioration where tilled when wet or with heavy machinery. Luvisols on steep slopes require erosion control measures.
Nitisols	Are among the most productive soils of humid tropics. Have deep, porous solum, stable structure to permit deep rooting and make soils quite resistant to erosion. Have good workability, internal drainage and fair water holding properties complemented by good chemical (fertility) properties. They have relatively high weathering minerals content and surface soils may contain high organic matter; in particular under forest or tree crops.
Ferrasols	Generally have good physical properties; such as soil depth, good permeability and stable microstructure, less susceptible to erosion. Friable when moist, easy to work, well drained but could be droughty because of low available water storage capacity. Has poor chemical fertility, scarce or absent weatherable minerals and weak cation retention capacity. Manuring, mulching and/or adequate fallow periods or agroforestry practices and prevention of soil erosion, are important management requirements.
Acrisols	Adapted rainfed and irrigated cropping systems with careful fertilization and management are required if sedentary farming is to be practiced. Most tree roots are concentrated in the humus surface horizon with only a few tap-roots extending down into subsoils. Rotation of annual crops with improved pasture maintains the organic matter content.
Vertisols	Large areas of Vertisols in semi-arid tropics are still unused or are used only for extensive grazing, wood chopping, charcoal burning etc. The soil has considerable agricultural potential, but must be well managed for sustained production. Its good chemical fertility and occurrence on extensive level plains where reclamation and mechanical cultivation can be envisaged are assets of Vertisols.
Arenosols	Arenosols are commonly coarse textured, accounting for their generally high permeability, low water and nutrient storage capacity. On the other hand, Arenosols offer ease of cultivation, rooting and harvesting of root and tuber crops.
Alisols	The generally unstable surface soil of cultivated Alisols makes them susceptible to erosion; truncated soils are quite common. Toxic levels of *Aluminium* at shallow depth and poor natural soil fertility are further constraints in many Alisols. Productivity of Alisols in subsistence agriculture is generally low.

Adapted from World Reference Base for Soil Resources (WRB, 2014).

Cultivation of some soils is limited by low water holding capacity; while others have poor permeability and weak root penetration; e.g., Arenosols, Ferralsols and Regosols (Table 2) . Some others are highly leached, resulting in medium to high acidity, moderate to low cation exchange capacity and base saturation, and low to very low organic matter content. Soil nutrient replenishment and soil quality restoration from organic and mineral sources is a prerequisite for continuous cultivation of most soils in Nigeria; particularly, under intensive production systems. Many of the soils are susceptible to erosion due to their locations in the landscape; resulting in gullying, relatively low organic matter content and fragile structure. Soil degradation and attendant depressed yields due to nutrient mining, impoverished soil quality/health, inappropriate soil and water conservation practices are wide spread in the country.

Conclusions

Soil degradation is widespread in Nigeria and continues unabated due to the absence of a 'National Soil Research Institute' with the mandate to oversee sustainable management of the nations' nonrenewable natural resource (soil). Integrated soil health/quality management approach should be adopted in agricultural soil use to ensure sustainable agricultural productivity, food security and environmental conservation. Detailed soil map of Nigeria focused on potentially agriculturally productive areas should be compiled to allow for planned sustainable intensification of agricultural production and the attainment of national food security.

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National priorities for sustainable soil management in Gambia

Abdou Rahman Jobe[1]

Summary

The Gambia is believed to be one of the Sub-Saharan African countries most seriously affected by land degradation. Current levels of land degradation have significant economic costs for the country. The need for sustained efforts at addressing the degradation problem through promoting and scaling up of Sustainable Soil/Land Management activities in The Gambia, therefore, remains relevant. In an effort to deal with the situation, a number of projects on land management are being or have been implemented with varying levels of successes achieved and useful lessons learnt. The situation can further be salvaged through a coordinated national and international investment effort and funding mechanisms. Partnerships involving a broad range of government and non-government stakeholders, including the public and private sector, bilateral and multilateral development agencies, and foundations can play a major role in sustaining Sustainable Soil Management (SSM) implementation in The Gambia. Furthermore, mainstreaming the concepts and principles of SSM into national economic development and sectorial policies/strategies of the government and other development and technical institutions would serve as a catalyst towards attainment of sustainable soil/land management which eventually will contribute to environmentally sound food self-sufficiency and security in the country.

Introduction

Land resources, including soils, are basic resources of agricultural production for food and markets. Their proper management is fundamental to enhancing the capacity and output of the sector, especially to meet macro-economic priorities of poverty reduction and economic growth. "The soil resources in the Gambia are fragile and not renewable, possessing relatively low fertility, taking into consideration the country's geo-physical location in the semi-arid to arid zone of West Africa, with a drought prone ecology. Current farming practices (crops and livestock) have not been helpful to prevent the depletion of the already limited fertility of the soil resources, especially their continuous use without soil cover, poor soil fertility management, and injudicious mechanization with tractor powered implements". (Ministry of Agriculture- Gambia. July 2009. Agriculture and Natural Resource Policy 2009-2015)

The Gambia's agricultural sector consists of four sub-sectors, namely (i) crops, (ii) livestock and poultry, (iii) research and development and, (iv) agricultural service providers. Agriculture is predominantly subsistence, using very little mechanization and inputs, and rain-fed, with very little irrigation. As such, the agricultural productivity is low, and the sector is especially vulnerable to droughts.

The need for sustained efforts at addressing the degradation problem through promoting and improvement of sustainable soil/land management activities in The Gambia, therefore, is important. However, it is recognized that the cost of implementing SLM activities over a large area is huge and cannot be easily borne by one institution or country. Yet, without such interventions, the expected achievements of enhanced livelihoods of many of the smallholder farmers who feed the nation will be an illusion and the country's socio-economic development as well as both human and environmental health will be adversely affected.

Recognizing the challenges faced by the agriculture and natural resources (ANR) sector, The Gambia's government in 1996 prepared Vision 2020 to transform the country into a middle-income, export-oriented nation by 2020, with the ANR sector as top priority. A series of policies, programs and strategies were then developed to improve the ANR sector's performance. In addition, a number of international donor-funded projects focusing on sustainable soil management have been or are being implemented.

Land use and degradation

The Gambia has a total land area of about 1.04 million ha, of which 558,000 hectares (or 54 percent) are arable. About 69,100 farm households cultivate 320,000 ha or 57 percent of the total arable land. Thirty percent (96,000 ha) of the cultivated area is devoted to groundnut production, while coarse grains, and rice production account for 144,000 ha (45%) and 72,000 ha (23%), respectively". (Ministry of Agriculture, Gambia. January 2015. The Gambia Sustainable Land Management Investment Framework 2016 – 2020).

Only about 57 % of the total arable land being put under cultivation is mainly attributed to the reason that the traditional farming population is ageing and can no longer effectively continue farming. The active young populations are not interested in farming but in white-collar jobs around the urban areas or in travelling to the west in search of so-called greener pastures. However, the government has already put strategies in place to reverse this trend, although the emphasis is more on productivity per unit area of land than total land put under cultivation. The National Entrepreneurship Development Initiative (NEDI) and the National Youth Service Scheme (NYSS) are initiatives introduced by government to motivate and incentivize youths to partake in agriculture. The Gambia is believed to be one of the Sub-Saharan African countries most seriously affected by land degradation.

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Within the country, land degradation is caused by a variety of complex inter-related degradation processes such as soil degradation. "The Gambia's soil resources have declined in productivity as a result of soil erosion, reduction in plant nutrient content, and adverse changes in their biological, chemical, physical, and hydrological properties. Water erosion has specifically led to removal of high amounts of soil from the uplands and depositing them in the lowlands". (Ministry of Agriculture, Gambia. January 2015. The Gambia Sustainable Land Management Investment Framework 2016 – 2020).

In an effort to deal with the situation, a number of projects on soil/land management such as the IFAD/AfDB funded Lowland Agricultural Development Project (LADEP), Global Environmental Facility project (GEF), Participatory Integrated Watershed Management Project (PIWAMP), National Agricultural Land and Water Management Development (Nema) Project, and the Sustainable Land Management Project (SLMP) are being or have been implemented, with varying levels of success achieved and useful lessons learnt. These projects have demonstrated the potential contribution of sustained improved land use and management to poverty reduction, enhancement of livelihoods, and the country's development as well as the attainment of the Millennium Development Goals (MDG).

The situation can further be salvaged through coordinated national and international investment efforts and funding mechanisms. Partnerships involving a broad range of government and non-government stakeholders, including the public and private sector, bilateral and multilateral development agencies, and foundations can play a major role in sustaining SLM implementation in The Gambia. The recognition of this by the government of The Gambia, and the fact that the funding required is in excess of its baseline funding justify the request for additional funding for implementation.

The Gambia's national priorities for sustainable soil management (SSM)

The Gambia's national priorities towards achieving sustainable soil management are:

- Sustained efforts at addressing the degradation problem through promoting and scaling up
- Capacity Building for SSM at all Levels: Efforts aimed at SSM in the country will not succeed if there is no capacity on the ground to implement the initiatives, no matter how well-thought out they are.
- Assessment of the human resources and institutional environment at all levels (national and decentralized) to determine their readiness for supporting SSM interventions.
- Development of effective SSM knowledge generation and management, Monitoring and Evaluation (M&E) and information dissemination systems.
- Collection of high quality soil data to serve as basis for land suitability evaluation, land use planning and sustainable soil management. The fact that much of the available data is outdated is a constraint and there is a need for updating the 1976 national land resources study.
- Development of new soil/natural resources and development policies.
- Support for knowledge sharing and innovation networks. This will support knowledge and innovation networks as well as sharing experiences within The Gambia and with other Sub-Saharan Africa countries. It will also support networking with other regional and international SSM and land administration networks and programs.
- Provision and acquisition of adequate modern soil testing materials and equipment, ranging from field and laboratory testing to digital map production equipment and material.

Conclusions

The Gambia is one of the Sub-Saharan African countries most seriously affected by land degradation, caused by a variety of complex interrelated degradation processes, including various types of soil degradation. Soil resources have declined in productivity as a result of soil erosion, reduction in soil nutrient content and adverse changes in their biological, chemical, physical, and hydrological properties. Water erosion has specifically led to removal of high amounts of soil from the uplands and depositing them in the lowlands. Therefore, mainstreaming the concepts and principles of SSM into national economic development and sectorial policies/strategies of the government and other development and technical institutions would serve as a catalyst towards attainment of sustainable soil/land management which eventually will contribute to environmentally sound food self-sufficiency and security in the country and the continent of Africa as a whole.

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Priorities for sustainable soil management in Ghana

Francis M. Tetteh[1] and Enoch Boateng[2]

Summary

Low soil fertility, nutrient mining, soil erosion leading to degradation and low use of fertilizers have contributed to low crop yields in Ghana. The maintenance, restoration and enhancement of soil health have been widely acknowledged as key elements in increasing agricultural growth and sustainable agricultural systems. Regulations to ensure supply and quality control of fertilizer will further contribute to the development of the fertilizer market in Ghana. Site specific and profitable fertilizer recommendations will be required to improve soil and crop productivity instead of current blanket recommendations in use irrespective of soil type, crop and environmental condition. The use of mobile soil test kits is a way of evaluating farmers' fields for rapid site specific soil management recommendations. The Ghana Soil Information Service (GhaSIS) project is designed to produce soil maps and other products for farmers to improve soil and crop productivity. Artisanal mining is a key agent for rapid soil and environmental degradation in Ghana. The cost of environmental degradation and negative impact on human health outweigh all other benefits.

Introduction

Agriculture in Ghana is faced with declining crop yields due to nutrient mining and erosion leading to soil degradation, weakened ability to maintain fertility and poor soil health. This is evident from huge yield gaps (FAO, 1995).

The main goal of government policy is to improve and sustain soil and crop productivity in order to reduce hunger and poverty and improve livelihoods of the citizenry. To achieve this goal the main activities being implemented are:

1. Development of soil health policies to address issues that can result in immediate and significant growth in productivity and livelihood of the small holder farmers by:
   - Promotion of fertilizer use,
   - Sensitizing stakeholders on regulations for implementing the fertilizer law (control of fertilizer quality, standards in warehousing, haulage, distribution of fertilizer, etc),
2. Developing and providing appropriate fertilizer recommendations for various crops.
3. Digital detailed soil mapping
4. Stemming land degradation caused by artisana or subsistence mining

Discussion

Promotion of fertilizer use

Fertilizer use rate in Ghana is very disappointingly low (less than 12 kg ha^{-1}) (MoFA- CSD, 2012)) while nutrient depletion rates range from about 40 to 60 kg of nitrogen, phosphorus, and potassium (NPK) ha^{-1} yr^{-1} (FAO, 2005), being among the highest in Africa. The target is to increase application rate to at least 50 kg ha^{-1}, as recommended in the Medium Term Agricultural Sector Investment Programme (METASIP), the policy document of the Ministry of Food and Agriculture. Fertilizer subsidies were introduced to promote fertilizer use and improve crop productivity of smallholder farmers. Farmers were encouraged to use the fertilizers on mainly the key food crops – maize, rice, millet and sorghum.

Implementation of fertilizer regulations (quality control, storage, haulage, misleading claims, short weights)

The Fertilizer Act has the purpose to regulate and monitor the production, importation and commercial transaction on fertilizers and related matters. This new law provides the foundation for the development of the fertilizer sector. Effective implementation of the regulations will also require sensitizing all stakeholders, including agricultural parliamentary committees, law enforcement agencies, farmers, etc., about the law and the regulations. The Government of Ghana therefore needs support to implement the regulations through sensitization of all stakeholders including parliamentarians and law enforcement agencies on the law and regulations.

Developing and providing appropriate fertilizer recommendations

A key limitation to farmer's use of fertilizer in Ghana is lack of appropriate fertilizer recommendations that could result in high yields and good profits for farmers. The OFRA (Optimizing Fertilizer Recommendation for Africa) project is to help improve efficiency and profitability in fertilizer use in Ghana within the framework of Integrated Soil Fertility Management (ISFM) practices under smallholder farming. The use of organic and inorganic fertilizer normally increases crop yields, when they are applied together especially, when the right fertilizer is applied, at the right time, right rate, in the right place and using he right method (Vanlauwe et. al. 2011).

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In order to evaluate the fertility status of soils and address the issue of site specific fertilizer recommendation, the International Fertilizer Development Centre (IFDC), in collaboration with Alliance for a Green Revolution in Africa (AGRA), is creating awareness of and promoting the use of portable soil test kits in improving soil fertility management. The programme is targeting soil fertility specialists, extension agents, fertilizer companies, input dealers and farmer based organizations as stakeholders. The use of soil test kits can provide quick assessment of the fertility of soils that can guide fertilizer

Digital detailed soil mapping (AfSIS, Global Soil Partnership)

The Ghana Soil Information Service (GhaSIS) which is an offshoot from the African Soil Information Service (AfSIS), is designed to meet stakeholder soil information needs, and assist with co-developing the databases, information products and services that will be most useful in managing soils, crops and landscapes appropriately. Some of the products and services envisaged are a soil fertility map, textural map, available moisture map, soil organic carbon map, crop suitability map, yield gap map, etc. Funds are, however, inadequate to implement the project fully.

Land degradation due to artisanal and small-scale (ASM) mining

In 2010, artisanal gold production rose to 23% with over 60% of the Ghanaian mining labour force directly dependent on it for their livelihood (Hilson, 2001). Artisanal mining is an activity that impacts on livelihood. Many factors like human health, pollution of drinking water, accelerated soil erosion, siltation of water bodies and irreversible destruction of agricultural lands outweigh the poverty reduction potential of ASM in the medium to long term. Government and artisanal miners should seek funds for rehabilitation and re-vegetation of the degraded soils. It takes about 100 to 1000 years to form 1 cm of soil depending on where you are.

Conclusion

Agricultural productivity in Ghana remains low due to low use and high cost of fertilizer, and low adoption of ISFM practices. The GhaSIS project has been designed to provide information and services based on diagnostic methods that use infrared spectroscopy and remote sensing to produce soil maps and other service products that are farmer friendly. There is the need to promote the use of mobile soil test kits for extension services and farmers. Sustainable management of the soil, water, and forest resources is required to arrest or stem the current pace of soil and environmental degradation in Ghana.

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Strategies towards sustainable soil management in Cabo Verde: environmental and livelihood challenges

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Summary

Soil degradation has seriously affected both people's livelihood and the environment in Cabo Verde, a country where only 10% of its reduced surface is arable land. To hold the soil in place, the water in the soil, maintain sustainable yields and combat land degradation, the governments have implemented a number of soil and water conservation (SWC) measures that are strikingly visible throughout the landscape. Notwithstanding the enormous efforts and the recognition of their benefits, a clear overview of their biophysical and socioeconomic impacts have been poorly assessed and scientifically documented. This paper presents an overview of the implemented strategies towards building resilience against the harsh environment, the state of soil degradation and its drivers, the existing SWC measures, and the recommended priorities for sustainable soil management in the country. Literature review, field assessments and expert judgment comprise the basis of this overview. Cabo Verde has faced its limitations with relative success by implementing an integrated governance strategy that involves awareness raising, institutional framework development, financial resource allocation, capacity building, and active participation of rural communities. However, with the limited soil resources still facing severe threats, it is crucial to implement SSM as the key to a more sustainable agriculture, food security and healthy soils.

Introduction

In Cabo Verde a combination of factors have resulted in extensive soil degradation, with negative consequences for the livelihood of the population and its fragile environment. The stabilization of the agricultural landscape with erosion control measures and the maintenance of sustainable yields became priorities for the country's' governments, both as environmental protection and survival of the population. The successive governments have focused their rural development policies on soil and water conservation (SWC) strategies to address desertification, water scarcity, and soil erosion, which have completely changed the landscape (Ferreira et al. 2013; Baptista et al. 2015a).

Efforts to reverse and prevent land and soil degradation focus on the concept of sustainable land management (SLM) and sustainable soil management (SSM), referring to the use of land or soil resources to meet present needs without compromising the ability of future generations to meet their own needs (Liniger et al, 2011). It includes the implementation of agronomic, vegetative, structural, and management measures to control soil and land degradation and enhance productivity (Schwilch, et al, 2012). As such, the SWC strategies implemented in Cabo Verde promote the SLM/SSM concept, often used interchangeably in this paper.

Investments in SLM measures are enormous at the national level, yet a clear overview of their extent and combined benefits on agricultural productivity, conservation effectiveness, sustainability, and livelihood, is still deficient (Baptista et al., 2015a).

This paper aims to present an overview of the implemented strategies towards building resilience against the harsh environment, the state of soil degradation and its drivers, the existing SWC measures, and the recommended priorities for SSM in the country.

Government initiatives to reverse harsh conditions

Throughout the history, Cabo Verde has experienced numerous events of crop failure and food insecurity that caused extensive starvation from the 16th to the 19th centuries, registering several famine episodes (Ferreira et al., 2013). To eradicate famine, governments had to provide work for people locally on the so-called FAIMO (High Intensity Labor Fronts), which was a national program that ensured jobs for thousands of people in rural areas, channeling the labor to the implementation of SWC measures.

The post-independence governments, facing successive dry years in the late 1970s and early 1980s, oriented their rural environmental actions towards combating desertification and soil degradation by elaborating strategic instruments, creating proper institutional frameworks, raising awareness, managing scarce financial resources, promoting effective stakeholder participation, setting policies and regulations and adhering to regional and international agreements. Because of these initiatives, Cabo Verde is currently recognized as a success case on transforming a harsh environment into a less hostile living environment and building resilience to absorb shocks from extreme drought periods, which no longer result in food crises and starvation.

Drivers of soil degradation and major soil threats

Climatic. Extended droughts have reduced vegetation cover, exposing bare soil to erosion, while heavy rainfall events during the wet season generate high rates of runoff, transporting enormous quantities of soil, seriously affects the quality of the environment, food security, sustainability and longevity of the limited arable land in the country. Water erosion and related nutrient losses constitute major threats to soil degradation in the country (Baptista et al, 2015b).

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Human. Human activity exerts strong pressure on the limited soil resources, contributing to soil degradation in several ways. These comprise: (1) Inappropriate agricultural practices such as intensive cultivation of steep slopes without adequate conservation measures and excessive weeding with hoe, (2) overexploitation of aquifers, resulting in salinization of soil in the valleys, (3) rural poverty, leading to deforestation due to tree cuttings for domestic use, (4) overgrazing and (5) impermeabilization of good agricultural soils by urbanization and road construction.

Topographic and pedological. Elevation strongly influences rainfall, with highest erosivity values at high elevations, coinciding with high rainfall, steep slopes and shallow soils, which make these areas susceptible to erosion (Figure 1).

Figure 1. *Main drivers of soil degradation: (a) burning of crop residue on field, (b and c) gully erosion due to cultivation of steep slopes with no protection, (d) gives an example of runoff loaded with sediment.*

Soil fertility loss. Despite the high natural fertility of the soils, intensive cultivation without adequate replenishment of soil nutrients through organic or inorganic fertilizers has resulted in the decline of soil fertility, particularly, in the dryland areas, where the only source of nutrients for maize crops comes from intercropped beans. The soil organic matter and carbon content is low (< 2%) due to lack of soil cover, removal of crop residue from farmlands and high rate of organic matter decomposition.

State of soil resources and management

Land use. Of the 4033 km^2 of land surface that the country comprises, about 10% (41,000 ha) is cultivated. The soils are mainly Regosols and Cambisols (WRB, 2014), i.e. soils with limited profile development, of volcanic origin, medium to coarse textured, steep, low in organic matter and generally shallow. Fertile soils (i.e. Kastanozems) are present on ancient surfaces. Soils of alluvial and colluvial origin are found in valleys, constituting the major areas for irrigated agriculture. Of the cultivated surface, >90% is used for rainfed agriculture while about 6.5% is used for irrigated agriculture. About 23% of the country's surface is forested.

Magnitude of soil erosion. Numerous efforts have been made to quantify erosion in the country both at plot (Smolikowski et al., 2001; Baptista et al, 2015b) and sub-watershed levels (Tavares, 2010), with results indicating great spatial and temporal variability depending on slope, land-use, rainfall amount and intensity. Mean erosion rates for traditional farming vary from 0.2 to 23 t/ha/yr at plot level and from 0.1 to 43 t/ha/yr at sub-watershed level. The smaller rates at plot level correspond to low slope areas and the larger to the steeper slopes. The large variability within results, the high rates of erosion and shallow soils on steep terrain require longer-term assessments to establish standard tolerable rates for Cabo Verde hillsides, allowing policy makers to better plan soil management interventions.

Existing conservation measures. Both structural and biological SWC measures were implemented, aiming to hold the soil in place, the water in the soil and to combat desertification. Structural techniques comprise check dams, contour rock walls, contour furrows, micro catchments, terraces and retaining dams. Biological measures consist of vegetation barriers with different species (i.e., Aloe vera, Leucaena leucocephala, F. gigantean), pigeon pea cultivation and reforestation with drought-tolerant species. Vegetative measures, including tree/shrub cover, implemented to protect the steep hillsides, are most widespread, reaching more than 80% surface cover in some watersheds. The implementation of SWC techniques modifies landscape functions at different spatial scales and they have produced dramatic changes both at plot and watershed scales. Figure 2 illustrates some soil conservation measures in the country, some of which (i.e., afforestation and Aloe vera hedges) have been documented as successful conservation measures (Liniger et al., 2011).

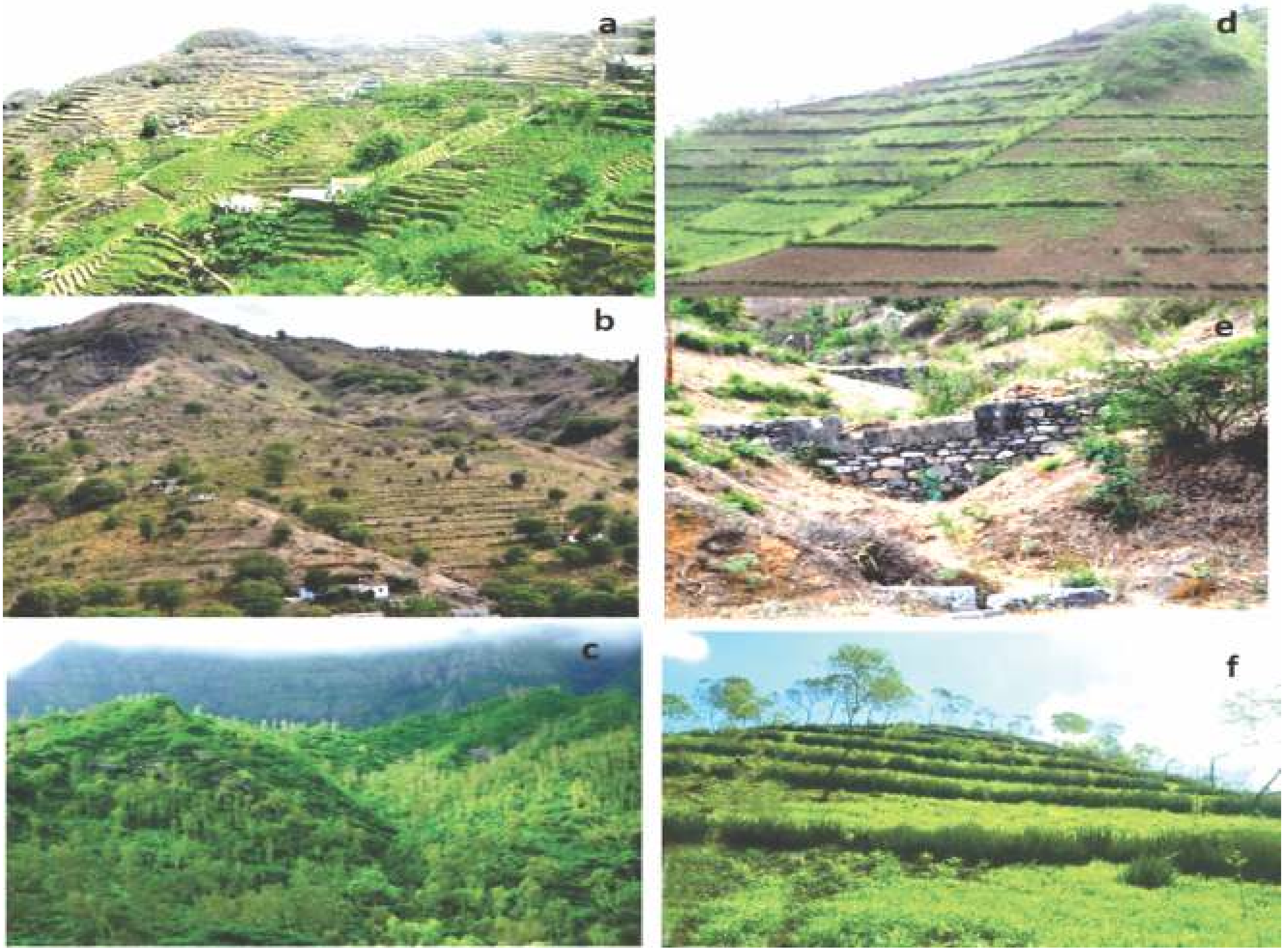

Figure 2. Vegetation and structural soil conservation measures in Cabo Verde: (a) terraces for irrigated agriculture, (b) contour rock walls, (c) afforestation in humid zone, (d) Leucaena leucocephala hedges,
(e) check dams on water ways, (f) Aloe Vera hedges

Monitoring and assessment (M&A) of sustainable soil management measures in Cabo Verde are still deficient. Recently, the implementation of the bottom-up approach project - DESIRE (Desertification Mitigation and Remediation of Land) contributed to fill part of the M&A gap for the Ribeira Seca Watershed , giving policy makers and implementing institutions a spatial overview of past and ongoing processes to allow planning of future activities. DESIRE developed an approach for establishing SLM strategies in response to desertification, consisting of five steps: (1) establishing land degradation and SLM context and sustainability goals with stakeholders; (2) identifying, evaluating and selecting SLM strategies with stakeholders; (3) trialing and monitoring SLM strategies; (4) up-scaling SLM strategies; and (5) disseminating the knowledge gathered (Schwilch et al., 2012). Successful SSM requires an effective monitoring system.

Priorities for sustainable soil management

The priorities to promote SSM should focus on the implementation of the following actions:

- Establishment of a harmonized soil information system or database;
- Assessment, monitoring and mapping of soil resources;
- Implementation and maintenance of soil conservation techniques, including afforestation and vegetation barriers in dryland;
- Research and adoption of SSM practices that promote soil cover, moisture retention and nutrient uptake such as integrated soil fertility and conservation agriculture systems;
- Awareness raising and participation of stakeholders through: (1) sensibilization of farmers, civil society, NGO's and rural communities for the importance of SSM, (2) Involvement of end-users in targeted soil research and in finding solutions for local problems, (3) multidisciplinary approach for identifying, prioritizing, testing, evaluating and implementing appropriate SSM techniques and tools to inform decision makers, and (4) scientific and community based approaches that promote integrated actions; and
- Increasing capacity building of research in soil degradation and SSM through: training of researchers, equipment of laboratories, development of targeted soil research, including best SSM practices, assessment of erosion, fertility management.

Policy recommendation and conclusion

In Cabo Verde, all the efforts in soil and water conservation measures aim to improve land management as a whole, while nowadays, there is also a need to address the soil as a limited and threatened resource to restore its productive potential, enabling food security. This calls for a concerted approach between stakeholders and the scientific community, similarly to the DESIRE approach, which could be up-scaled to the National level and integrated into long-term programs.

With the limited soil resources facing severe threats, it is crucial to implement SSM as the key to a more sustainable agriculture, food security and healthy soils. Unless authorities take serious priority actions to reverse the soil degradation process, soil degradation neutrality may be an unrealistic goal to attain in Cabo Verde and sub-Saharan Africa, in the near future.

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Sustainable soil management in Niger: constraints, challenges, opportunities and priorities

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Summary

Soil degradation is a significant contributing factor to low agricultural productivity, poverty, and other social and environmental issues in Niger. Many Nigeriens view land degradation as one of the main causes of poverty and vulnerability, along with population growth and drought. Soil fertility depletion and soil erosion are also major problems in both croplands and rangelands, resulting from the low and declining use of fertilizers, the lack of fallow, the expansion of farms into marginal lands, overgrazing of rangelands, deforestation, droughts, land tenure insecurity, violent winds that lead to highly erosive torrential rains, and other factors of natural resources fragility. Sustainable Soil Management (SSM) is one of the priorities in Niger. Therefore, the importance given to land degradation through this brief SSM paper is to be considered in light of increasing awareness for public and private financing. In this context, guidance in improving the effectiveness of sustainable land management (SLM) investments is critical.

This orientation paper mainly targets natural resource management (NRM) activities as one component that will regenerate land and water resources. It addresses the status of soils, their constraints and potentials and identifies priorities and awareness measures.

Introduction

Niger is a large Sahelo-Sudanian country with a surface area of 1,267,000 square kilometers and about 17 million inhabitants. The country is bordered in the North by Libya and Algeria, in the East by Chad, in the South by Nigeria and Benin, and in the West by Burkina Faso and Mali.

Niger has experienced a series of food crises (1973, 1984, 2001, 2005, 2010), which reveal a number of drivers of which the most important are: the tendency for the climate to dry up and the high population growth (3.3%), which exceeds agricultural growth (estimated at 2.5%), thus leading to an increasing pressure on the environment. The combination of all these factors inevitably leads to a change in ecological balances and to land degradation. This has resulted in the abusive exploitation of lands, often beyond the actual capacity of ecosystems and has led to considerable loss of their productive potential. The maintenance of these fragile ecosystems is, however, indispensable for conducting all the socio-economic activities of rural populations. Rural economy constitutes the main livelihood leverage of rural populations through agriculture, livestock, fisheries and forestry (Ichaou and Maisharou, 2013).

The land degradation induced by ecosystem changes generates considerable losses in terms of agricultural income. As is the case for most sub-Saharan countries of the circum-Sahara, Niger is ravaged by significant desertification and land degradation phenomena which impart poverty among populations, especially those living in rural areas. The degradation is manifested mainly in the formation of large bare areas that promote water erosion; the formation and enlargement of gullies, often on cultivated land; the formation of moving sand dunes which is one of the most acute land degradation issues, especially in the eastern part of the country; the sanding up of crop lands, water bodies, agricultural production basins and various socio-economic infrastructures (roads, houses, etc.); salinization of irrigated farmland; leaching of nutrients; soil crusting; the reduction of plant cover and the loss of biodiversity.

The effects of this degradation and its various forms translate naturally into the disorganization of production systems, the decline in rural productions (notably agriculture, livestock and forestry); the drop in households' income and the persistence of food insecurity.

To overcome this situation, Niger has for the past two decades adopted measures for the conservation of soil and water and to promote natural regeneration with the help of technical and financial partners. This has enabled the country to acquire the needed experience in Sustainable Land and Water Management (SLWM). Unfortunately, despite this accumulated experience, the phenomenon of land and landscape degradation is steadily worsening under the effect of climate change and human pressure, thus compromising the various efforts made. Hence, the development of best practices in the area of SLWM is necessary.

Among the best practices identified in Niger, this paper presents those that have the potential of protecting farm and pastoral land and strengthening the resilience of biophysical systems.

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Soil status

Soils are heterogeneous and need an integrated system to manage their fertility. Meanwhile fertilizers are expensive and often unavailable. Most soils have low fertility and with poor cultural practices these soils are plagued by losses of nutrients through the removal of crop residues. Soils are especially poor in phosphorus and nitrogen. In many parts of Niger, even virgin or fallow lands are poor in P and N (Henao and Baanante, 2006), contributing to low soil productivity.

Large agro-ecological zones, constraints and challenges related to fertility, degradation and soil and water conservation

The climate in Niger is characterized by two main seasons: a long dry season that lasts about eight months and a four-month rainy season starting in May or June in the Southern part of the country. Between the Saharan, Sahelian and Sudanian zones, rainfall varies from 0 to over 700 mm annually. The Sudanian zone in the south covers only 1% of the territory. Over the past 30 years, isohyets have significantly moved towards the south under the effect of seemingly long-term climate changes. Meanwhile, due to demographic pressure, farmlands have extended towards the north, into lands that are always more prone to erosion.

Most of the soils used in rainfed cropping are ferruginous tropical soils and sub-arid brown soils. Their sand content varies between 80 and 90% and their clay content between 1 and 8%, with a low silt content of between 2 to 6%. Their water retention capacity is very low, with a field capacity of between 5 and 12%. They are generally acidic, with a pH (Water) varying between 4.5 to 7, and poor in organic matter (0.15 to 0.7%), and are phosphorus (0.4 to 9.4 mg /kg soil) and nitrogen deficient.

Technical challenges

Taking into account the entire degraded land, choosing appropriate techniques and species as well as selecting those that are best adapted to specific sites, require specific expertise. Often, a protected area is regenerated while man-made pressures on neighboring areas are exacerbated.

Priorities

The following recommendations are made to the government or relevant authorities regarding supporting sustainable soil management:

- Create a conducive socio-economic and policy environment to enable producers to invest in the soil sector (Henao and Baanante, 2006) and sustainable soil fertility management.
- Create/strengthen the capacity of a soil institute in regard to (i) capable human resources and (ii) appropriate equipment
- Create a platform for SLM innovation and community involvement
- Create/strengthen extension, advisory, technical and economic support services.
- Create a communication plan towards the various partners and public targets for soil science education
- Ensure that SLM scientists are represented among policy makers
- Establish Farmer Field Schools and SLM demonstration sites (Feder *et al.*, 2004)

Best practices to overcome the issues and challenges

Food security should be the focus of sustainable soil management. The extension of best practices is a solutions package that should lead to resolving many problems and overcoming challenges in the area of soil degradation and contribute to the sustainable management of agricultural and pastoral lands.

Over the years several highly effective indigenous soil and water conservation practices have been developed by the local populations in Niger and neighbouring countries in the Sahel region, like Burkina Faso and Mali. These have been implemented very successfully especially after the devastating droughts of the 1970s. Badly degraded areas are being regenerated and food security improved. The effective sustainability of the implementation of these practices is due to the fact that it is community driven, with communities taking mental "ownership" of their own projects and thus being committed to them. Government does not impose itself on the projects, nor is descriptive, but is in the background available in a supporting role when needed and requested. The practices include (i) stabilization of dunes with suitable shrubs/trees (Plate 1), (ii) stone bunds (Plate 2), (iii) sometimes combined with mulching (Plate 3), (iv) resulting, for example, in good sorghum production as seen on the left of Plate 4 in a formerly bare area that looked like that on the right and in the foreground ;(v) planting pits, called "zai" and elsewhere "tassa", with manure or compost applied in the pit (Plate 5) (vi) "demi-lunes" ("halfmoons"), in which grain crops (Plate 6) or fodder for lievstock (Plate 7) can be grown.

Plate 1: Dune fixation with *Euphorbia balsimefera*

Plate 2: Building stone bunds

Plate 3: Combining stone bunds with mulching

Plate 4 : Stone bunds resulting in good sorghum growth (left)

Plate 5: Planting pits (Zais) combined with the use of organic matter.

Plate 6: Half moons planted with sorghum

Plate 7 : Half moons planted with animal fodder grasses

Conclusion

The soils in Niger are characterized by low soil fertility, poor water holding capacities, vulnerability to soil physical degradation, like crusting, faced with wind and water erosion and various other challenges.

Good SSWM practices have a good potential for strengthening the resilience of populations and ecosystems, controlling the effects of climate change and securing and improving the life of rural populations. They can be applied on a larger scale and benefit thousands of farmers and pastoralists.

The large participation of beneficiaries in the implementation of these measures mobilizes the rural population, thus reducing implementation costs and constituting a significant investment in the productive resources of the beneficiaries. It also promotes sustainability. These good practices constitute an efficient means to improve water management and reduce the degradation of soils, vegetation and biodiversity while increasing and stabilizing agrosylvopastoral yields. They thus contribute to mitigating the effects of climate change and significantly improving food security and the resilience of rural populations to external shocks. The integration of a sound use of natural resources in land planning promotes land tenure security, reduces risks of conflicts and links with communal and regional planning.

While land management is a promising solution for countries such as Niger, it however requires a long-term commitment. Covering sufficient areas to obtain a significant impact not only at individual farm level, but also on larger areas, is a multigenerational task that requires national continuous effort on the part of governments to organize the implementation and monitoring in SLM, their enhancement and maintenance. Without this orientation and external monitoring, the implementation of these works will lose its dynamics.

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Can Nigerian soils sustain crop production? - The dilemma of a soil scientist

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Summary

The greatest threat to sustaining agricultural productivity in Nigerian farming systems is the decline in soil productivity as a result of continuous crop production without appropriate soil management. This has also led to decline in per capital food production over the last two to three decades. Information from soil survey and research is an essential requirement for ensuring efficient land use and sustainable soil management practices. However, soil survey and research data are either scarce or not available to guide sustainable use of soil. These pedological data are fundamental in minimizing food insecurity through appropriate use of sustainable soil management systems. This is the dilemma confronting soil scientists in Nigeria. This paper is an attempt to identify the dilemma being faced by soil scientists in providing solutions to sustainable use of Nigerian soil resources. The paper reviews sustainable land management in Nigeria and adequate land use planning as a prerequisite for sustainable use of land and makes appropriate recommendations regarding requirements to ensure sustainable use of Nigerian soil resources.

Introduction

One of the major factors responsible for food insecurity in Nigeria is poor crop yield due mainly to unfavorable soil conditions. A large proportion (70%) of the soils in Nigeria is made up of low activity clay (LAC) soils which cannot naturally sustain crop production on a continuous basis (Ogunkunle, 2009). The population explosion of the last few decades has put great pressure on the available resources resulting in soil degradation of various types. The yields of most Nigerian crops are low in spite of the high yielding varieties that are being grown (Table 1). Unfortunately both the average yields and the average yields expressed as percentage of the potential yields of especially staple grains are very low. This has been attributed to inherent poor soil conditions and soil degradation. There is an urgent need for a well-planned scientific soil management strategy to control and prevent degradation and ensure favorable conditions for use of the soils for increased and sustained crop production. In an assessment of the productivity of soils in Africa, Salako (2010) reported that Nigeria is among countries with mainly low to medium productivity soils which can be improved with good management. Not all lands are suitable for agriculture and the lands that are suitable for cropping exhibit various degrees of suitability. They may also be suitable in the short term, but not for sustainable continuous crop production. This is where sustainability becomes the key issue and the dilemma of the soil scientist. The dilemmatic situations confronting the Soil Scientists in Nigeria can be summarized as follows:

- No one listens - individuals, farmers, land users and government care little about the misuse of land in Nigeria.
- The above leads to unchecked misuse of land, as reported by Fasina (1997 and 2001a), loss to erosion, desertification and other forms of land degradation.
- The economic sustainability being clamored for is not related to land/soil management and thus not to agricultural and/or environmental sustainability.
- On the face value, the soils look productive, but they are fragile - low activity clay (LAC) soils that have very low inherent soil fertility and are vulnerable to degradation.
- Nigeria has no national soil classification system and major global systems do not enable suitable soil classification at detailed level.
- Nigeria has no national land suitability evaluation system.
- Nigeria has no soil information data base that can be used for land suitability evaluation and land use planning.

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Given the problem statement outlined above, the overall objective of this paper is to discuss issues relating to sustainable use of Nigeria's soils for sustained optimal crop production. The specific objectives are: (1) To identify and discuss issues on sustainable land management in Nigeria and Africa. (2) To evaluate land use planning as a prerequisite for sustainable use of soils. (3) To make recommendations on how to sustain Nigeria's soil resources.

Sustainable land management in Nigeria

Nigeria, like the rest of Africa, cannot achieve sustainable food security without sustainable land management. There have been many definitions for sustainable land management. Smyth and Dumanski (1995) defined it as a management system that combines technologies, policies and activities aimed at integrating socio-economic principles with environmental concerns to achieve the five-fold objectives of productivity, security, protection, viability and acceptability, while Greenland (1994) defined it as a system that does not degrade the soil or significantly contaminate the environment while providing necessary support for human life. Ogunkunle (2009) clearly stated that the different definitions differ with the differences in the emphasis placed on factors of management.

Some very obvious reasons have been advanced for the need for sustainable land management in Nigeria and Africa. Ogunkunle (2009) listed some of these reasons as:

(I) Rapid population growth and increasing pressure on the limited land resources.

(ii) Agricultural practices, coupled with poor management, have been responsible for considerable natural resource degradation.

(iii) The problem of decline in productivity and/or high cost of food that may occur in the event that the non-renewable resources on which production is based runs out.

(iv) Traditional agricultural systems, some of which are sustainable, are fast disappearing and being replaced by farming systems that are more intensive than vulnerable resources can tolerate and are dependent on finite fossil fuels and off-farm resources.

(v) The development of additional lands for agricultural purposes requires substantial investments to improve soil fertility, availability of water, irrigation, drainage and erosion control. These are often also marginal soils that are more vulnerable to degradation.

According to the review of Junge et al. (2008) on soil conservation in Nigeria, substantial work has been done to develop technologies that can reverse or prevent land degradation and sustain productivity. It indicates that there is no agro-ecological zone in Nigeria that soil scientists and agronomists have not covered to address issues related to sustainable land management. Among the technologies which have been tested are: (i) Mulching (ii) Cover cropping (iii) Intercropping (iv) Alley- cropping (v) Ridging or Tied ridging (vi) Conservation tillage or no tillage (vii) Planted fallows and Natural fallows.

Experience in southwest Nigeria has shown that while the various soil management technologies proposed by researchers increase soil productivity adequately on undegraded soils, it is difficult to sustain productivity of previously degraded soils beyond one or two years with these technologies, without a long term fallow or adequate application of soil amendments (Shittu and Fasina, 2004; Salako et al 2007b; Tian et al 2005). Shittu and Fasina (2004) tested the potential of appropriate plant residue management as a basis for sustainable maize production for two years in Ado–Ekiti (Table 2). They observed that surface mulching residue had a better yield potential for maize production in Nigeria. According to their study, the only treatment with the worst grain yield in the second year was where stubble was removed completely through bailing, thus indicating that removal of stubble is a non-sustainable practice. They therefore concluded that plant residues should not be removed in order to avoid nutrient loss and reduction in yield of maize. The insignificant difference between the effects of burning and non-burning of the residues indicates that the benefit from non-removal of the residue was due to its return of plant nutrients to the soil which could increase soil organic matter in the long run. The result also indicated that decrease in biomass and grain yield was due to reduction in soil organic carbon content. This is corroborated by Pantami et al. (2010) who reported decrease in soil organic carbon content as a result of burning and this was attributed to oxidation of organic carbon because most organic colloids are altered by soil heating from 100-250^{oC}. Studies by Ojeniyi and Adejobi (2002) and Owolabi et al (2003) showed that higher nutrient uptake and crop yields are benefited by succeeding crops of bush and residue burning due to the dissolved ash which serves as liming and fertilizing materials. However, this is short-lived.

Table 1: Average and potential yield of cereals and tuber crops in Nigeria

Crop	Average yield (t/ha)	Potential yield (t/ha)	Average yield relative to potential yield (%)
Upland rice	0.8 - 1.2	1.5 - 2.5	50
Lowland rice	1.0 - 2.0	2.5 - 8.0	29
Maize	1.5 - 2.0	3.5 - 10.0	26
Sorghum	0.5 - 1.2	2.0 - 2.5	38
Millet	0.5 - 1.0	1.0 - 2.0	50
Cassava	11 – 12	20 – 25	51
Cocoyam	5 – 6	8 – 10	61
Irish potato	10 – 12	14 – 15	76
Sweet potato	10 – 12	14 – 15	76
Yam	12 – 14	18 – 20	68

Source: Ogunkunle, 2009.

Table 2: Percent Change in Field Dried Cob Weight (t/ha) and Maize Grain Yield (t/ha) After Treatment with Different Residue Management

Treatments	Field dried cob weight (t/ha)			Maize grain yield (t/ha)		
	2001	2002	% change	2001	2002	% change
Burnt residue left on surface	5.7[a]	5.4	-5.2	3.2[ab]	3.1[a]	-3.1
Incorporation of burnt residue	5.4[a]	5.3	-1.6	3.5[a]	2.7[ab]	-22.9
Incorporation without burning	5.2[a]	5.2	0	2.9[b]	3.3[a]	13.8
Surface mulching	3.9[b]	5.2	33.3	2.5[b]	3.4[a]	36.0
Bailing	6.1	4.9	-29.6	3.8[a]	2.1[b]	-44.7
(S.E)	(0.39)			(0.36)		
CV%	24.3+			32+		

Means for treatment over the two years having the same superscript letter are not statistically significant
Source: Shittu and Fasina 2004

Note:Negative value indicates percent reduction LSD at 5%
Figures in parentheses indicate standard error at P<0.05
(-) indicates coefficient of variability

Land use planning – a prerequisite for sustainable use of soils

Land use planning is the process of evaluating land and alternative patterns of land use and other physical, social and economic conditions for the purpose of selecting and adopting the kind of land use and courses of action best suited to achieve specified objectives (Purnell, 1988). Land use planning aims to make the best use of limited resources by: (i) Assessing present and future needs and systematically evaluating the land's ability to supply them. (ii) Identifying sustainable alternative uses and choosing those that best meet these needs. The goals of land use planning define what is meant by the "best" use of land.

Optimum land use efficiency is achieved by matching different land uses with the areas that will yield the greatest benefits at the least cost. Fasina (1997) in a study in Lagos State, Nigeria, recommended some plausible land use plans for selected sites in Lagos State in line with the quality of the soils identified within the selected area. Land use planning is best carried out by a multi-disciplinary team, to make possible a holistic approach to use of the land. Proper land use planning is the basis for a sustainable land use and strong productive agriculture. This means diagnosing land use problems, generating viable options for tackling them and getting information about the consequences of adopting each option to wherever decisions about land use is being made (Fasina 2004).

In Nigeria and Africa, there is a serious problem of allocation of land to wrong uses. Hardly is any thought ever given to the nature of land being allocated to urban, residential and industrial development. Lands are bulldozed for roads, airports and vast areas acquired for residential and industrial development, irrespective of the agricultural qualities of the soils or the environmental impact of these uses (Fasina 2001a). Consequently scarce areas with potential cropland are lost permanently for crop production. Fasina (2001a) and Idachaba (1992) discussed the major constraints to land use planning as a prerequisite for the sustainable use of soils, including among others: (i) Lack of considering alternative land uses and soil management frame-works. (ii) Poor data base. (iii) Very limited improved land development and management technologies and capacities. (iv) Generalized fertilizer recommendations. (v) Land tenure security problems. (vi) Problems related to abandonment of or changes to slash and burn rotation and bush fallow technology. (vii) Poor public perception and lack of economic education.

It was against the background of these persistent constraints in land use planning, sustainable soil management and the implementation difficulties and failure of previous projects that the National Agricultural Land Development Authority (NALDA) was created in Nigeria to address the constraints listed above. However, there is need to develop a national framework for alternative land use planning and sustainable soil management in Nigeria. The main elements pointed out by Fasina (2013) should include: (i) A land use planning and sustainable soil management in support of agro-ecological specialization in production. (ii) Serious commitment to fight deforestation and desertification. (iii) Provision of data on land use and soil management. (iv) Generation and dissemination of improved land development and soil management technologies. (v) Disengagement of government from direct involvement in fertilizer importation and distribution, since this is not efficient.

Conclusion and recommendation

Soils in Nigeria are not as fertile as people believe. The soils require development and implementation of special management approaches beyond appropriate fertilizer application, some of which have been developed, to support food production on a continuous sustainable basis. There is need to establish a National Soil Research Institute to handle all issues relating to sustainable soil use and management.

Based upon the discussions above, we wish to suggest the following recommendations which if implemented can help sustain the Nigerian soil resources:

1. Production of a detailed soil map for Nigeria: A high quality detailed soil map is a prerequisite for efficient land use planning and sustainable land use. The federal government of Nigeria should assemble qualified pedologists and other experts under a national soil research institute to produce a detailed soil map for Nigeria while providing them with every needed logistics.

2. Creation of awareness for the need for land use planning and sustainable soil management in Nigeria through general education and public enlightenment: Both government and the Soil Science Society of Nigeria should take leading roles in this.

3. Promulgation and implementation of appropriate legislation relevant to land use and soil conservation. This is the responsibility of government, but should be done in consultation with the country's soil scientists to ensure that it is appropriate and relevant for Nigeria. On one hand, cultivation of non-arable land should not be allowed while on the other hand, prime and unique agricultural land should be reserved for agriculture. Strict appropriate soil conservation measures should be defined and enforced, especially on marginal land.

4. Nigerian tertiary institutions must be strengthened to train soil scientists who can contribute meaningfully to continuous sustainable use of the country's soil resources: These scientists must both have good basic scientific soil knowledge and be exposed to the specific properties and characteristics of Nigerian soils and their management requirements. Constant review of soil science curricula at both undergraduate and postgraduate levels should be done to meet the requirements of 21st century sustainable land use management.

5. Adequate funding of soil research: Government should shoulder the responsibility to provide adequate funding for soil research in Nigeria on a continuous basis. Research institutions must be well equipped and well-staffed.

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Siltation of major rivers in Gonarezhou national park, Zimbabwe: a conservation perspective

Edson Gandiwa[1] and Patience Zisadza-Gandiwa[2]

Summary

This article focuses on siltation in major rivers in the greater Gonarezhou ecosystem, potential impacts of siltation on wildlife conservation and options to reduce the siltation challenge in southeast Zimbabwe. Data were collected through field observations between 2005 and 2013, and literature review. The results show that the three major rivers, namely Mwenezi, Runde and Save, in Gonarezhou National Park are highly silted. The major cause for the siltation is attributed to land degradation due to anthropogenic activities. Strategies to minimise siltation including integrated river basin management and sustainable land use approaches are suggested.

Introduction

Globally, freshwater ecosystems are under threat from anthropogenic activity and climate change (Magadza, 1994; Mantyka-Pringle et al., 2014; Midgley and Bond, 2015). In particular, poor land use practices have led to increased soil erosion resulting in siltation of major rivers (Ananda and Herath, 2003; Kidane and Alemu, 2015). Siltation of major rivers has negative implications on biodiversity, ecosystems, livelihoods and economic dimensions (Dudgeon, 2000; Schuyt, 2005). Thus, understanding the extent of siltation of major rivers is important for developing strategies to protect the freshwater ecosystems. Gonarezhou National Park (GNP) in southeastern Zimbabwe has over the years witnessed increasing siltation of its major rivers. However, long-term data on siltation of the major rivers is not available, pointing to the need of temporal and spatial analysis of these major rivers to determine the historical siltation status and trends. This article is aimed at advancing our understanding on siltation of the major rivers, potential impacts of siltation on wildlife conservation and suggests options to reduce the siltation challenge in the greater Gonarezhou ecosystem.

Methods

Study area

This study focuses on GNP (~5,050 km^2) located in the southeastern lowveld of Zimbabwe (Fig. 1), between 21° 00'–22° 15' S and 30° 15'–32° 30' E. Established in the early 1930s as a Game Reserve, GNP was upgraded into a National Park under the Parks and Wildlife Act of 1975. GNP is part of the Great Limpopo Transfrontier Conservation Area into which conservation areas in Zimbabwe, Mozambique and South Africa have been integrated into one. The park has a semi-arid climate with long-term annual rainfall of approximately 466 mm and is endowed with diverse wildlife species (Gandiwa and Zisadza, 2010) and savanna vegetation dominated by mopani (*Colophospermum mopane*) woodland (Gandiwa, 2011). Three major rivers traverse the park, namely Mwenezi River (57 km), Runde River (77 km) and Save River (32 km) (Gandiwa et al., 2012a; Zisadza-Gandiwa et al., 2013).

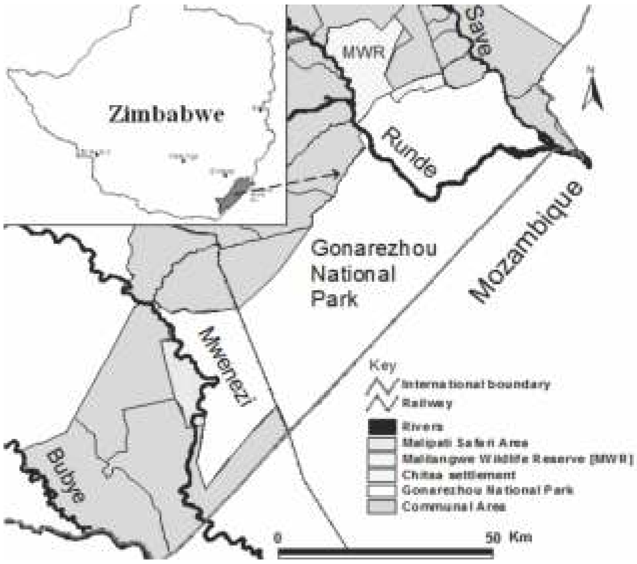

Fig. 1. Location of Gonarezhou National Park showing major rivers in southeast Zimbabwe. Source: Gandiwa et al. (2012b).

Data collection and analysis

Data were collected through field observations within the greater Gonarezhou ecosystem between 2005 and 2013, and review of published scientific literature of work conducted in GNP. Data were qualitatively analysed and presented along major themes related to the potential impacts of siltation on the Gonarezhou ecosystem and wildlife conservation.

Results and discussion

Status of major rivers in Gonarezhou national park

The three major rivers in GNP, i.e., Mwenezi, Runde and Save, are highly silted (Fig. 2). Field observations have shown that Runde and Save rivers have continuous flow throughout the year whereas Mwenezi River is characterised by isolated large pools in the driest periods of the year.

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Fig. 2a Mwenezi River

Fig. 2b Runde River

Fig. 2c Save River

Fig. 2. Status of siltation of three major rivers in Gonarezhou National Park, southeast Zimbabwe, September 2012. Photo credits: P. Zisadza-Gandiwa and Gonarezhou Conservation Project.

Causes of siltation

Siltation of the major rivers in GNP is largely caused by upstream human activities, including poor agricultural activities such as riverbank cultivation, lack of contours in the agricultural fields, overstocking and consequently overgrazing, settlement expansion, loss of vegetation cover through uncontrolled fires, and uncontrolled removal of trees and wetland destruction for utilization of these areas for farming activities. Furthermore, natural processes such as sheet erosion and weathering also contribute to the siltation of major rivers in GNP. However, it is likely that the contribution of the natural processes to the siltation is very small compared to anthropogenic influences. Land degradation has been identified as the cause of siltation and consequently reduction of surface stream water resources (Magadza, 1984). Siltation is also prevalent in other smaller rivers within GNP, e.g., as witnessed by the siltation of Benji Weir, primarily from erosion which may have been exacerbated by animal concentration near water sources, and loss of vegetation cover from fires and herbivory (Tafangenyasha, 1997).

Potential impacts of siltation on ecosystems and wildlife conservation

Upstream and downstream of GNP, the three major rivers play an important role for local people (e.g., household water provision, gardening), agricultural production (e.g., sugarcane plantations), water provision for livestock and economic activities such as aquaculture. However, with increased siltation of the three major rivers there is a direct negative impact on the mentioned ecosystems services and/or activities. Also, loss of soil in the adjacent communal areas degrades the land, making it less productive and increasing the vulnerability of local people to extreme events such as droughts and floods. Given that the water resource is shared with neighbouring countries, within the Great Limpopo Transfrontier Conservation Area, it is important to enhance integrated river basin management (Gandiwa et al., 2012a), and reduce soil loss and river siltation for the benefit of livelihoods and wildlife conservation in the region.

Siltation of major rivers in GNP impacts negatively on river health as the remaining flowing water is prone to increased pollution from upstream sugarcane plantations as silt acts as a vehicle for certain pesticides and phosphates which affect aquatic life downstream through nutrient loading and reduced dissolved oxygen. The fine sediment loading in GNP rivers smother the river bed and kill off invertebrates and fish eggs, resulting in reduced spawning success and/or inevitable aquatic biodiversity losses. Moreover, the reduction in volume of water flow and also pool size has negative implications on hippopotamus (*Hippopotamus amphibius*) and crocodile (*Crocodylus niloticus*) populations along the major rivers (O'Connor and Campbell, 1986; Zisadza et al., 2010; Zisadza-Gandiwa et al., 2013). The high concentration of wildlife species in and around remaining large pools may lead to animals fighting for territories, e.g., hippos, with some of the displaced animals moving to the sections of the rivers outside the park which results in human-wildlife conflicts since such species are regarded 'problem animals' in the area, because they destroy crops and kill people.

Other negative implications of loss of larger pools due to siltation include reduced wildlife viewing opportunities, less opportunities for recreational fishing, and disappearance of species that prefer flowing water. These would have negative economic impacts due to the area becoming less attractive for tourists. On the other hand, remaining large pools can easily form hotspots for illegal fish harvesting (Gandiwa et al., 2012b) and also illegal hunting of wildlife as they concentrate in the areas with water, especially during the dry season. Concentration of wildlife in such spots also leads to very serious overgrazing and increased erosion. This in turn aggravates the siltation problem.

The reduced water flow along the major rivers has a direct influence on wildlife species distribution and habitat utilisation as animals commonly concentrate near the water sources hence likely leading to localised habitat degradation of some vegetation communities especially from elephant (*Loxodonta africana*) activity (Gandiwa et al., 2011). Increased siltation will likely have a direct impact on surface water availability within the park as the major rivers, natural water pans, and two weirs/dams are the main sources of water for wildlife in GNP. The current management plan for GNP discourages further artificial water provision within the park as a way of encouraging the natural regulation of wildlife populations (ZPWMA, 2011).

Loss of large pools may also impact negatively on cultural activities such as *saila* (annual fish drives) where local people gather and sustainably harvest fish in some of the largest pools. Prospects for developing cultural tourism products related to festivals will not materialise if the current siltation trends are not managed. Furthermore, wildlife dispersal will change following surface water availability and distribution. In turn, such changes have cascading impact on sport hunting in the adjacent communal areas under the communal areas management programme for indigenous resources (CAMPFIRE).

Conclusion

This article shows that the major rivers in GNP are highly silted largely through land degradation from anthropogenic activities upstream. Given the potential challenges that climate change will have on the study area (Gandiwa and Zisadza, 2010), it is thus important to be proactive on ways to minimise siltation in the major rivers in GNP. Therefore, the following are recommended:

- Promoting sustainable land use management approaches upstream of the major rivers traversing through the park, e.g., through discouraging stream bed cultivation and illegal artisanal mining along rivers and their catchments;
- Enhancing integrated river basin management;
- Enhancing awareness campaigns and education on ways to minimise land degradation;
- Enhancing river health monitoring systems; and,
- Ensuring that there is continued water flow downstream in catchments with some dams as a way to ensure continued ecosystem functioning within the protected area.

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Comparative study of the production of maize cultivars tolerant of low-nitrogen soils, with and without fertiliser in the Democratic Republic of the Congo

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Summary

To determine the profitability of the production of maize varieties tolerant of low-nitrogen soils (low-N), a study was conducted at the Mvuazi Research Centre. Seven low-N varieties were compared with two local varieties with and without fertilizer. Statistical analyses proved a significant different among the varieties (P<0.05) in both conditions (with and without fertilizer). The average yield with fertilizer was higher than the yield without fertilizer. LNTP-W C4 and LNTP-Y C7 varieties recorded the highest yields of 7,142.8 kg/ha and 7,120.5 kg/ha respectively with fertilizer as compare to 5,960.9 kg/ha and 3,625.6 kg/ha without fertilizer. The production cost of one kilo of grains without fertilizer was 213.52 Congolese Francs (FC) as compared to 216.79 FC with fertilizer. The gross profit margin without fertilizer was 286.48 FC as compared to 283.21 FC with fertilizer. These results show that the use of low-N varieties can improve the productivity of nutrient-poor soils of farmer fields while minimising production cost.

Introduction

In Africa, maize yields in farmer fields range from 1 to 2 t ha^{-1}, in contrast to the yields of 5-7 t ha^{-1} reported in research stations in developed countries [7], and in commercial farms in those countries. The low yields are due to nutrient-poor soils [3] and the high cost of inputs [2].

Several studies have proven that 30-50 kg/ha of NPK fertilizer, combined with 5 t/ha of organic fertilizer (manure) produce grain yields closer to those of 100-120 kg/ha with mineral nitrogen alone [6]. The only constraint associated with the use of this technology is the availability of adequate quantities of manure. Many studies have shown that there are some maize genotypes that can effectively use the nitrogen from the soil [10]. These genotypes can improve the productivity of nitrogen-poor soils and minimise the use of inorganic fertilizer, and thereby increase gross profit margins. The aim of this study was to compare the productivity of low-N tolerant cultivars in terms of their grain yields and the corresponding cost of production with a view to minimising the use of fertilizers in farmer fields.

Materials and methods

The study was conducted at the INERA research centre of Mvuazi in the Democratic Republic of Congo (470 m of altitude, 14°54'E, and 5° 21'S). The seeds were planted with 75 cm × 50 cm spacing. Two seeds were planted per hole in two rows of 5 m long in two different conditions: without fertilizer and with fertilizer. The fertilizers were NPK 17-17-17 (250 kg/ha during sowing) and 60 kg/ha of urea (46% N) on the 15th and 30th days after sowing. Seven low-N cultivars from the International Institute of Tropical Agriculture (IITA), namely *BR 99 TZL Comp 4 DMSRSR* (V1), *BR 9928-DMRSR LN C1* (V2), *LA POSTA SEQUIA C6* (V5), *LNTP-W C4* (V6), *LNTP-Y C7* (V7), *TLZ COMP 1 C6 LN C1* (V8), *TZPB Prol C4* (V9) and two local cultivars (V3 and V4) were compared. A randomized complete block design was used. Only grain yields and profit margins were determined. The general linear model variance was analysed and significant differences were noted up to 5%.

Results

Yields were higher with fertilizer than without fertiliser for all cultivars (Table 1). The variance analysis showed a significant difference (P<0.05) among cultivars in both cases. Where fertilizer was applied the highest yields were recorded for V6 and V7, although these were not statistically significantly higher than with V1, V4 and V9.. Very important was the very good yield of V6 without fertilizer. It actually gave a higher yield without fertilizer than six of the other cultivars gave with fertilizer. V5 and V7 also gave fair yields without fertilizer. These results show the importance of selecting appropriate cultivars, where fertilizer is available and even more so where fertilizer is not available.

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Table1. Grain maize yields with and without fertilizer

Varieties	Yield (kg/ha) WITH	WITHOUT
V1	6,393.4±703.8 bc	2,239.1±544.4 a
V2	3,813.4±254.3 a	1,439.5±644.2 a
V3	3,551.2±420.8 a	2,001.4±661.2 a
V4	5,675.9±85.3 bc	2,244.4±642.3 a
V5	4,886.3±1,796.3 ab	3,105.01±503.9 ab
V6	7,142.8±198.6 c	5,960.9±1,643.2 b
V7	7,120.5±226.3 c	3,625.6±584.4 ab
V8	4,972.01±449.9 ab	1,472.2±384.2 a
V9	5,000.4±388.5 ac	2,038.9±104.9 a

The profit margins per hectare obtained with the nine maize cultivars are very illuminating (Table 2). The production costs were 213.52 FC without fertilizer and 216.79 FC with fertilizer. The maize was sold at 500 FC per kg (1US$ = 950 FC). The highest profit margin per hectare was obtained with V6 without fertilizer, with V6 and V7 with fertilizer close to it and V1 not far behind.

Table2. Profit margins (gross margins) for nine maize cultivars with and without fertilizer

Cultivars	WITH		WITHOUT	
	Sale (thousand FC/ha)	Profit (thousand FC/ha)	Sale (thousand FC/ha)	Profit (thousand FC/ha)
V1	3196.7	2084.7	1119.5	637.1
V2	1906.7	794.7	719.8	237.3
V3	1775.6	663.6	1000.7	518.2
V4	2838.0	1725.9	1122.2	639.7
V5	2443.2	1331.2	1552.6	1070.1
V6	3571.4	2459.4	2980.5	2498.0
V7	3560.3	2448.3	1812.8	1330.3
V8	2486.1	1374.1	736.1	253.6
V9	2500.2	1388.2	1019.4	537.0

Discussion and conclusion

Several studies on plant selection for the purposes of improving yield on low-nitrogen soils have been conducted on tropical maize [4]. The results of our study are an indication that the use of fertilizer in required proportions increases grain yields appreciably for all cultivars used. Both without and with fertilizers there were very big differences between different cultivars. Without fertilizer, the highest yield was recorded by V6 cultivar, being even higher than the majority of other cultivars gave with fertilizers. V6 and V7 were chosen specifically on account of their reported ability to tolerate low-nitrogen soils [9]. Plants are according to their photosynthesis pathway classified as C3 or C4 plants. C4 plants are very efficient plants; among other in the utilization of N. Maize is a C4 plant, but not a perfect example. Some cultivars are closer to being good C4 examples than others and in the present study cultivars totalling a number of cycles corresponding to C4, that is, being better C4 examples such as V6, V7 recorded the highest yields where fertilizer was not applied, with V5, V6 and V7 also giving the highest yields where fertilizer was applied. These results are in agreement with those of Ajala & al. (2007) [1] and Menkir & al (2006) [8]. According to Bertin & gallais (2000) [5], the difference in production between the maize lines in their study was due to differences in their ability to effectively absorb nitrogen.

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Effect of no-tillage with mulching on yield of east African highlands banana intercropped with beans at Mulungu, in the eastern Democratic Republic of Congo.

Tony Muliele Muku[1]

Summary

The objective of this study was to assess the effect of no-tillage with mulching on yield of East African highlands banana (Musa AAA-EA) in banana-beans intercropping systems. Two treatments were compared: Conventional manual tillage (CMT) with export of crop residues (= T0), and No-till with banana residues mulch (= T1). Bunch weight was monitored from 15 mats per treatment replicate throughout 4 crop cycles. Banana yield (t ha^{-1} cycle^{-1}) was calculated on basis of the average bunch weight and plant density (2,500 plants ha^{-1}). Treatment and crop cycle had significant effects on banana yield. For all crop cycles, T1 treatment had higher yields, with on average 42 t ha^{-1} vs 36 t ha^{-1} obtained in the T0 treatment. Banana yield under T1 increased by 6.7, 8.1, 21.3, and 22.9% in the first, second, third and fourth cycles, respectively. It is be concluded that CMT with export of crop residues had negative impact on the yield of East African highlands banana, and should be avoided by farmers interested to banana yield.

1. Introduction

Banana-beans intercropping systems are commonly practised in South Kivu (DR Congo) in order to increase crop productivity and maximize land use. At the onset of bean cropping seasons (September and February), the soil between banana rows is tilled manually to a depth of 15-20 cm, using a hand hoe or a fork to prepare the seedbed for the beans (Dowiya et al., 2009; Muliele et al., 2015). Farmers believe that tillage improves the bean performance, but tillage may possibly seriously damage the superficial banana root system and consequently negatively affect banana productivity and increase nematode pressure (Muliele et al., 2015).

Many studies (e.g. Blomme, 2000; Lassoudière, 1978) have documented positive correlation between bunch weight or banana yield and below ground biomass. It is, therefore, expected that any decrease in root biomass may lead to decreased production. It is thus hypothesised that pruning roots to the depth of tillage twice a year by conventional manual tillage (CMT), and the lack of permanent soil cover will have negative effects on banana yield. A study was, therefore, conducted at Mulungu site, comparing conventional manual tillage (CMT) with export of crop residues with no-till (NT) with mulching.

Hence, the objective of this study was to assess the effect of no-tillage with mulching on yield of East African highlands banana intercropped with beans.

2. Materials and methods

The study was carried out at Mulungu research station (2.335°S, 28.788°E, 1699 m above sea level), South-Kivu in Eastern Democratic Republic of Congo. The soils are Nitisols (WRB, 2014) i.e. high quality fertile soils, developed on volcanic ashes. The soil properties of the topsoil at the study site are presented in table 1. The climate is Aw3, a tropical climate with 3 months of dry season (Peel et al., 2007). Annual average precipitation varies between 1500-1800 mm, and the growing season extends to over 325 days per year (Muliele et al., 2015).

The experiment was started in April 2008 in a land previously under CMT for sweet potatoes (*Ipomoea batatas*). A randomized complete block design with four treatments and four replications was applied: Conventional manual tillage (CMT) with export of crop residues (= T0), no-till (NT) with self-mulch (T1), NT with self-mulch + *Hyparrhenia diplandra* grass mulch (T2) and NT with self-mulch + *Tripsacum laxum* grass mulch (T3). Self-mulching consisted in leaving crop residues (banana and beans after harvest) in the field. External mulches (T2 and T3) were applied at the rate of 25 t ha^{-1} dry matter (DM) in the first year, and 12.5 t DM ha^{-1} in the second year. Since the external mulch (T2 and T3) treatments did not affect banana yield significantly in the first and second cycles they were abandoned thereafter. A single application of banana residues mulch (22 t DM ha^{-1}) was applied in T1 plots at planting only. T0 plots were tilled at the onset of each bean growing season (September and February) to prepare the seedbed for beans. Bush beans were sown in all treatments at a density of 250,000 plants ha^{-1}. No mineral fertilizers, organic manure or pesticides were applied. We assumed that beans had no significant effect on banana yield. Sword suckers of banana cultivar "Ndundu" (AAA-EA beer banana) were planted at a 2 m x 2 m spacing (2,500 plants ha^{-1}). Cultural practices consisted of de-suckering, male bud removal and weeding. Bunch weight was recorded through four consecutive cycles, and banana yield (t ha^{-1}) was then calculated for each cycle. Bean yield was assessed during six growing seasons, but was not affected by treatments. Data analysis was performed using the Statistical Analysis System package (SAS 9.2 Enterprise Guide 4.2).

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3. Results and discussion

Table 2 shows that T0 treatment had the lower yield whatever crop cycles. Statistical analysis revealed significant difference ($P<0.05$) between T0 and T1 in the fourth cycle. The lower banana yield under T0 treatment may be principally attributed to tillage-induced mechanical damage on banana rooting system, and/or the lack of permanent soil cover. Differences in yield between T0 and T1 could not be primarily related to soil fertility since soil fertility properties were not affected by treatments (Muliele et al. 2015).

The lower banana yield in the T0 treatment compared with the T1 treatment during cycle 4 (Table 2) is in agreement with the lower root length and biomass, and plant growth previously reported by Muliele et al. (2015) for the same experiment. This may confirm the strong correlation between the banana root system and above-ground biomass reported by many authors (e.g. Blomme, 2000; Lassoudière, 1978). Muliele et al. (2015) reported that the renewal of banana rooting system subsequent to tillage requires several months. Thus, if CMT occurs in the flowering or fruit formation stage, which is a critical period for water and nutrient uptake, a lower water and nutrients uptake due to decreased rooting system may adversely affect the performance of banana. A gradual increase in difference in banana yield between T0 and T1 treatments through crop cycles (6.7-22.9%) may indicate an increase of stress with increased number of tillage events.

The lowest yield was observed in the first cycle (33 t ha^{-1}, mean of all treatments) compared with other ones (37-49 t ha^{-1}). For banana (*Musa* spp.), many studies (e.g. Njuguna et al., 2008) reported lower banana yield in the first cycle compared to those of subsequent cycles, due to better plant establishment at the latter cycles than in the first one. We conclude that CMT with export of crop residues in banana-bean intercropping systems had negative impacts on banana yield. To increase the yield of East African highlands banana farmers should adopt the NT systems. Further observations are needed and should be aimed at testing the effects of no-till systems on banana yield in other banana production areas in the East African highlands.

Table 1. Physico-chemical properties of the topsoil (0-20 cm) at Mulungu site. Values are means ± standard error.

Soil properties	Values
Ntotal(%)	0.42±0.01
Ctotal (%)	5.15±0.15
Exch. Ca (cmolckg^{-1})	18.98±0.75
Exch. Mg (cmolckg^{-1})	4.47±0.19
Exch. K (cmolckg^{-1})	1.23±0.16
P available (mg kg^{-1})	86.39±4.24
pH (H_2O)	6.3±0.04
Texture	Clay

Source: Muliele et al. (2015). N_{total}: total nitrogen, C_{total}: total organic carbon.

Table 2. Banana yields (t ha^{-1}) under different soil tillage systems. Values are means (n=4) ± standard error.

	Treatments			
Crop cycles	T0	T1	T2	T3
C1	30.1±1.8a	32.1±1.9a	33.7±2.5a	35.0±2.0a
C2	46.8±3.7a	50.6±3.2a	49.1±4.3a	51.0±4.6a
C3	35.5±4.2a	43.1±1.7a	Nd	Nd
C4	33.6±2.5a	41.3±1.8b	Nd	Nd
Overall mean	36	42	41	43

Nd: not done. Means (horizontal comparison) with the same letters are not significantly different ($P=0.05$).

Acknowledgments

Author gratefully thank the DGDC, Belgium who, through CIALCA (Consortium for Improving Agriculture-based Livelihoods in Central Africa), has funded a part of this study. Thanks also go to Mrs Cécile Diaka for funding additional data monitoring.

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Agro-economic efficiency of mineral and organic fertilization of beans on the ultisols of the highlands of eastern Democratic Republic of the Congo

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Summary

Permanent land occupation by intensive crops (beans, maize, and cassava) has led to serious crop yield reductions in eastern Democratic Republic of the Congo. Study during two successive growing seasons demonstrates agro-economic efficiency of mineral and organic fertilization on beans induced by few options available and suitable for local fertilization conditions. Compared to control, NPK (120kgha^{-1}) indicate improvement in yields by 57 to 95% and value-cost ratio (VCR) of 1.5 and 4.46 in the first and second growing seasons respectively, manure (10T/ha) improved yields by 90 to 95%. Combine manure (5T/ha^{-1}) and NPK (60kgha^{-1}) increased yields by more than 100% and indicate VCR of 1.3 and 1.64 in the first and second growing seasons respectively. It is therefore possible to improve beans production in upland eastern DRC and investments are covered after two growing seasons, resulting in benefits in terms of crop production and income.

Introduction

Low soil fertility is among the most important yield-limiting factors in the bean producing highland regions in eastern parts of the Democratic Republic of Congo (DRC). The major soil fertility related problems are found to be low available phosphorus (P) and nitrogen (N), and soil acidity, which is associated with aluminum (Al) toxicity (Lunze et al. 2002). In light of these constraints, farmyard manure (FYM) and compost application are the most common practices on smallholder farms (Musungayi et al. 1990). To be effective in bean (Phaseolus vulgaris L.) production requires that they must be well decomposed (Gurung and Neupane 1988). Furthermore, large quantities have to be applied (Lunze 1990; Ngongo and Lunze 2000), which are not accessible to the majority of smallholder bean growers (Thung and Rao 1999). According to Vanlauwe et al. (2010), these technologies should be based on their relevance to local conditions inherent to both the biophysical and socio-economic environment of farmers. In this study, we assess the agro-economic efficiency of local farmyard manure alone or in combination with mineral fertilizer.

Methodology

The study was conducted in the highlands Ultisols of eastern DR Congo where the soils have clayey texture (sandy clay loam), low soil pH, low base saturation and relatively high organic C contents (Pypers et al. 2010). To increase bean production NPK at a rate of 120 kg.ha^{-1} or local cattle farmyard manure (FYM) at a rate of 10 t.ha^{-1} were applied as a single dose just before planting. Only at Mulungu a combination of 60 kg.ha^{-1} NPK plus 5 t.ha^{-1} FYM was also applied as a single dose at planting. Experiments were conducted at three sites, namely at the research station at Mulungu and in farmers' fields at Mulengeza and Kashusha. Treatments were laid out in a randomized complete block design (RCBD) with eight farmers chosen randomly in each on farm site as replications. Data were collected on grain bean yield and subjected to an analysis of variance to assess the effect of each treatment, using GenStat 3th Edition. The effects of the different treatments were compared by computing the least standard deviation (LSD). Significance of difference was evaluated at P=0.05. Agro-economic analyses, consisting of calculating the value-to-cost ratio (VCR) and also the agronomic efficiency (AE) of the key nutrient (for beans being phosphorus, P) were done for the Mulungu site, where all three fertilizer treatments were applied. This is just a case study example to show the importance of doing these types of analyses. The calculations were done as follows:

$$VCR = (Y2-Y1)\,\mu/x \qquad \text{Equation (1)}$$

Where: Y2= yield (kg) produced in the treated plot, Y1 = produced yield (kg) in the control, (Y2-Y1) = additional yield (kg) due to the treatment, μ = price of 1kg of the product and x = fertilizer cost.

$$AE = (Y2-Y1)/y \qquad \text{Equation (2)}$$

Where: (Y2-Y1) is as above and y = quantity (kg) of P applied.

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Results and discussions

1. Treatment effects on bean yield

At Mulungu yields were higher in the second season than in the first season. Yields in the first year increased by 57% and 91%, compared to the control, when NPK (120 kg/ha) or FYM (10 t/ha) were applied respectively, while the combination of 5 t/ha FYM and 60 kg/ha NPK increased the yield by 164%, i.e. it gave a yield 2,64 times that of the control (Table 1). The latter combination also gave a statistically significantly higher yield than high rates of NPK or FYM alone. FYM alone was slightly, but not significantly better than NPK in both seasons. In the second season all treatments increased yields by more than 100% compared to the control, the increase with NPK plus FYM combination being 170%.

Table 1: Effect of mineral and organic fertilizer on bean yields at Mulungu site in two consecutive seasons

Treatment	Bean yield (kg/ha)		
	Season 1	Season 2	Cumulative
Control	432.69a	500a	932.69a
NPK (120 kgha ^{1})	678.42ab	1065.10b	1743.52b
FYM (10 tha ^{1})	827.99b	1229.17cb	2057.16bc
NPK (60 kgha ^{1}) + FYM (5 tha ^{1})	1143.16c	1351.56c	2494.72c
LSD	244.3	273.3	465.9
CV (%)	15.9	16.7	12.8

Means followed by the same letters in the same column are not significantly different at p=5%

At **Kashusha** yields were also higher in the second season than in the first season where NPK or FYM was applied (Table 2). At Kashusha both NPK and FYM more than doubled yields, compared with the unfertilized control, in the first season. In the second season FYM increased the yield to more than three times that of the control in this low yielding soil, while NPK increased the yield to almost four times that of the control. In the first season FYM did slightly better than NPK, whereas NPK did slightly better than FYM in the second season. The cumulative yields with NPK and FYM were almost the same after two seasons.

Table 2: Effect of mineral and organic fertilizer on bean yields at Kashusha in two consecutive seasons

Treatment	Beanyield (kg/ha)		
	Season 1	Season 2	Cumulative
Control	299.58a	272.44a	572.02a
NPK (120kgha $^{-1}$)	637.50b	1025.64b	1663.14b
FYM (10tha $^{-1}$)	677.8b	913.46b	1591.26b
LSD	164.7	313.5	527.5
CV (%)	28.4	9.9	33.6

Means followed by the same letters in the same column are not significantly different at p=5%

At **Mulengeza** yields were also higher in the second season than in the first season (Table 3). In the first season NPK gave far more than double the yield of the control, while FYM gave a three times higher yield. In the second season NPK gave a yield more than double that of the control, while FYM also increased the yield significantly. In this season the yield with NPK was statistically higher than that with FYM. NPK gave a somewhat, but not statistically significant, higher cumulative yield the FYM over the two years.

Table 3: Effect of mineral and organic fertilizer on bean yields at Mulengeza in two consecutive seasons

Treatment	Bean yield (kg/ha)		
	Season1	Season 2	Cumulative
Control	273.33a	462.07a	735.4a
NPK (120 kgha^{-1})	696.25b	1089.74c	1785.99b
FYM (10 tha^{-1})	814.17b	806.62b	1620.79b
LSD	373.2	196	455.8
CV (%)	36.3	11	22.2

Means followed by the same letters in the same column are not significantly different at p=5%

2. The value-to-cost ratio and the agronomic efficiency analyses for Mulungu site

These analyses were done as a case study example to show how important it is to do these types of analyses. It must be kept in mind that the outcomes of such analyses are unique for each case, because the costs of different inputs and the sale prices of produce differ widely between different areas and also between different seasons in the same area. It must be kept in mind that a value-to-cost ratio (VCR) of 1.0 is the break-even point. In other words, when the VCR is above 1.0 it is profitable to apply fertilizer, but if it is below 1.0 a loss is suffered due to the fertilizer application. In the present example NPK and NPK plus FYM in the first season gave VCR values above 1.0 that were of the same order, with the combination being slightly inferior (Table 4). This despite the fact that the combination gave a 70% higher yield than NPK alone, being statistically significantly superior (Table 1). FYM alone gave a VCR value of far below 1.0. In other words it was not an economically viable option, despite it giving a 22% higher yield than NPK alone. In the second season NPK alone gave a very high VCR of 4.46. The VCR for the combination was of the same order as in the first season, but was vastly inferior to that for NPK alone. This despite the fact that the combination gave a 30% higher yield, statistically significantly superior to NPK alone. FYM alone again gave a VCR lower than 1.0. From an economic point the very high input cost of the manure compared with a much lower input cost for the inorganic NPK fertilizer was an important economic determinant. The manure part of the combined fertilizer clearly also hampered the profitability of the combination, despite its good yield response. This is quite opposite to the normally perceived situation in Africa. This is due to the small number of livestock in the study area following the two decades of repetitive wars; characterized by the looting of animals by militiamen and soldiers of the regular army. Making it therefore difficult to obtain a sufficient amount of manure by farmers in the region.

The differences in VCR were not related to the agronomic efficiency of the P in the fertilizers (Table 4). NPK, the most profitable fertilizer, had the poorest agronomic efficiency (AE) values. In the first season it was not statistically inferior to FYM but was percentage wise much lower. The combination fertilizer gave excellent AE values in both seasons. In the first season it was far superior to the others. In the second season it was not statistically significantly better, but still 49% higher than NPK alone.

Table 4: Cost effectiveness and agronomic efficiency of inorganic NPK fertilizer and farmyard manure for beans

	VCR	AE	VCR	AE
NPK (120 kg/ha)	1.50	12.05	4.46	28.26
FYM (10 t/ha)	0.45	19.76	0.65	35.74
NPK (60 kg/ha) + FYM (5 t/ha)	1.37	47.36	1.64	42.16
LSD	0.9ns	18.6*	1.56*	16.92ns
CV (%)	36.1	30.2	40.1	27.6

LSD– Least standard of difference and ns – not significant. * LSD significant at $P \leq 0.05$.

Treatments as experienced in this study had significant effects on production. Marginal rates of observed yields met the minimum value of 118% (CIMMYT, 1998). Economics analyses at Mulungu site show that, 1$ USD invested in fertilizer gain 0.5 $ USD and 3.46 $ USD respectively in the first and second season. In fact, benefit on investment in fertilizer can be obtained despite the high fertilizer price in the area, which is more than twice as high as in Kenya and Uganda (Pypers et al., 2010). The economic analyses show that when the VCR is above 1.0 it is profitable to apply fertilizer, but if it is below 1.0 due to the poor quality of the technology (Sebahutu, 1988); a loss is suffered due to the fertilizer application. Makinde et al. (2007) demonstrated this in cassava–legume intercropping systems, increasing net benefits by on average 700$ USD ha^{-1} (value-to-cost ratio of fertilizer use=6.7). However, in this study case, benefit from use of local FYM requires very large quantities that are very expensive to the majority of bean growers who are smallholder farmers as indicated above given the insecurity state of the area following the two past decades of repetitive wars in eastern D.R. Congo. Adjei-Nsiah et al. (2007) advised that technologies should suit the needs and resources available to the target farmer groups.

Conclusion

The study demonstrates the possibility to increase bean production in the Ultisol of eastern Democratic Republic of Congo highlands and how important it is to do economics analyses. The study demonstrates also, that the outcomes of economics are unique for each case, because the costs of different inputs and the sale prices of produce differ widely between different areas and also between different seasons in the same area. The use of local FYM do not increase bean yields nor improve benefits probably due to both the poor quality and high price of the amendment. Considering the socio-economic conditions of bean-producers in the study area, combining mineral fertilizer and local FYM at small rate may have benefits, but cannot simply replace the mineral fertilization (NPK), because it has high returns. Methodologies are therefore needed to stimulate acceptance by local farmers, and may include reduced delay of applying fertilizer. Although inorganic fertilizer has highest benefit, a better understanding of the conditions under which local FYM (available) is obtained can enable better targeting and adaptation of the relative technologies.

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Physico-chemical Properties of Soils Under Oil Palm Plantations of Different Ages

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Summary

The removal of forest cover for oil palm cultivation has raised concerns especially in the wake of issues and discussions revolving around climate change and its associated effects. The nature of pruned materials from the trees do not make them suitable for use as mulch cover on the whole farm but are heaped at some areas on farms. The objective of this study examined the changes in some soil physical and chemical properties under oil palm plantations with time in the Eastern Region of Ghana. Oil palm plantations of different ages (0-5, 5-10, 10-15, 15-20 and 20-25 years) were chosen based on similar land history. Sites selected were fairly located at the bottom slope on Oda soil Series (Aeric Endoaquent). On the same farm two different samples were taken; first under alleys; and secondly under heaped pruned branches. A reference site (uncultivated) also located on Oda soil Series was selected from a forest reserve and used as a standard (control). Particle size analyses showed that all soils were of sandy loam texture. All soils were acidic with pH below 5.5, relatively low CEC and with low per cent base saturation. Bulk density values varied with age and depth. Soils under prunnings had relatively lower bulk densities than those under alleys. Nitrogen content was largely dependent on C content since it was derived from the mineralisation of OM which served as the main source of N supply in the absence of external input.

Introduction

To meet the growing demands for food and other services, agriculture has had to undergo some form of transformation (Serpantié, 2003). In the Eastern Region of Ghana interventions have led to growing of various cash crops such as cacao, rubber, coffee, etc. instead of food crops due to the strongly acid, extremely infertile, highly weathered and highly leached soils present in this area. Among the high value perennial tree crops oil palm has been adopted and grown by smallholder farmers and other private agencies and government. Oil palm production has been documented as a cause of substantial and often irreversible damage to the natural environment. Clay (2004) reported that the negative impacts of oil palm on the environment include deforestation and habitat loss of critically endangered species and a significant increase in greenhouse gas emissions (Bates et al., 2008). There have also been arguments that oil palm is a nutrient miner and adds nothing to the soil. However, during cultivation of oil palm local farmers engage in pruning and the heaping of palm fronds (leaves) in between the rows of plants. Most of these farmers do not add any external input to their farms. The heaping of palm fronds has been observed to be a source of organic material addition to the soil. This material has been found to play a vital role in the maintenance of soil organic matter (SOM) and nutrient cycling in most smallholder and large scale oil palm farming systems in the tropics (McNeil et al., 1997; Cadisch et al., 2002b). This management practice by farmers serves as a potential means of contributing C to the soil under oil palm. From an agro-ecological perspective, OM and its main constituent carbon play a crucial role in the functioning of these ecosystems. They actually affect physical, chemical and biological properties of soils which influence growth (Batjes, 2001; Feller et al., 2001). There is a need therefore to assess the soil quality under smallholder oil palm plantations with particular reference to pruning and heaping of palm fronds on farms to assess the beneficial effect of this management practice on soil properties. The objectives of this research were to assess soil physical and chemical properties under pruned heaps in already established oil palm plantations of different maturity ages and to examine the dynamics (changes) over time under frond heaps in these plantations.

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Materials and methods

Private oil palm plantations owned by local farmers within the Kwaebibirim District of the Eastern Region of Ghana were selected with a reference soil, (uncultivated forest soil) taken from the Forest and Horticultural Crops Research Centre, Okumaning within the same district. These oil palm farms were at different maturity ages from very young ones of about three months old to farms as old as twenty-five years. Sampling of farms begun with creating five clusters according to age of oil palm plantation into which various farms were grouped. A total of fifteen farms were selected for sampling with three farms representing each age group as replicates. Soils were sampled from a depth of 0-10 and 10-20 cm. The various age groups considered were 0-5, 5-10, 10-15, 15-20 and 20-25 years. Sampling was preceded by marking out an area 25 m by 25 m. These sampling plots contained both alleys between rows of palm trees and pruned and heaped palm fronds within the palm rows. Core samplers were driven into the ground to take undisturbed soil samples within the alleys and under heaped branches for bulk density analysis. Sampling under the prunings was done carefully, especially under old heaps, since there was the need to distinguish the top layer from the decomposed material sitting just above it. Soils from the sampled spots from each farm were put together to obtain a composite sample. A sub-sample was taken, air dried, crushed and sieved through a 2 mm sieve and processed for laboratory analyses.

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Bulk density, particle size analysis (Bouyoucos Hydrometer, Day (1965)), pH ($CaCl_2$) (Electrometric), Organic Carbon (Wet Oxidation, Walkley and Black (1934)), Total Nitrogen (Kjeldahl Digestion, Bremner (1960)), Exchangeable bases and CEC (1M Ammonium acetate solution at pH 7.0) were among the properties determined. Genstats (12th Edition) and Minitab (16th Edition) were used for computer analyses. Separation of means was done using the Least Significant Difference (LSD) method particularly Tukey family test method of means separation in Minitab. All tests were conducted at a significance level of 5%.

Results and discussion

The physico-chemical properties of soils are presented in Tables 1 and 2.

Pruning and heaping of palm fronds on farms starts from 5 years onwards and so marks the beginning of dynamics distinct from 0-5 years. The 0-5 years samples enable comparison between the reference and cultivated site just after clearing.

Particle size analyses showed that the texture of all the soils was sandy loam. The minor differences observed in texture could be attributed to spatial differences between soils with less variation associated to cultivation. A general increase in bulk density with depth was observed under both prunings and alleys. This may be attributed to the increasing clay content with depth. Bulk density values under prunings were relatively lower than those of the alleys as a result of the influence of organic matter which made the soils in the 0-10 cm layer relatively loose as compared to those in the 10-20 cm layer where OM content was quite low. Organic matter played a key role in improving the physical properties of the soil, thereby contributing to the structural stability (Schnitzer and Khan, 1975) as has been seen in the BD values under prunings (Table 1).

The average pH values did not differ significantly between the 0-10 and 10-20 cm layers. The pH of soil within the oil palm alleys became lower than those under pruned fronds as the number of years increased. The forest soil was acidic. Opening up the forest caused a further increase in acidity (drop in pH). Similar results have been published by Nye and Greenland (1965) for this district. The low pH of the soils may be due to the nature of the parent materials and to the high rainfall (usually 2000mm and above) (Tweneboah, 2000) which causes intense leaching of basic cations in the forest soil. The low pH values imply the presence of a positively charged colloidal surface capable of attracting negatively charged ions. The different amounts of organic material present at each location contributed to slightly higher pH under prunings than within the alleys.

Exchangeable K in the uncultivated soil at 0-10 cm depth was higher than the various groups of oil palm soils both in alleys and under palm fronds. At 10-20cm depth exchangeable K is extremely low in both forest soils and oil palm soils. The exchangeable Na trend appears to be higher in the oil palm soils both in alleys and under heaped fronds. It is lower at both depths for all time groups than in the uncultivated soil. The level of the exchangeable Na appears to be too low to cause any concern about any possible soil physical impact. As shown in Tables 1 and 2, there is a definite trend for exchangeable Ca to be much lower in all time groups of oil palm soils in both the alleys and under heaped fronds than in the forest soil at both depths, especially at 0-10 cm, and is a little lower in the alleys than under heaped fronds. The data show that there is a definite trend for Mg to be much higher in the uncultivated soil than with cultivation at both depths. In general, the exchangeable Mg values initially tended to increase with time in both alleys and under heaped fronds but declined steadily with further age of plantation.

The low values recorded for the basic cations could be due to the low organic matter content and kaolinitic dominated clay fraction (Owusu-Bennoah et al., 2000). This also reflected in the low per cent base saturation of less than 30%. Per cent base saturation (PBS) of the uncultivated soil decreased slightly with depth while a general increase was seen under alleys with depth. The trend with age of plantation is somewhat inconsistent. The low PBS could also be explained by the high rainfall which leaches more basic cations out of the top layer and low organic matter thereby affecting CEC values.

Table 1 Physico-chemical properties of soils under oil palm heaps and the reference (uncultivated) soil

No.	BD	pH	K^+	Na^+	Ca^{2+}	Mg^{2+}	CEC	BS	TN	OC	BD	pH	K^+	Na^+	Ca^{2+}	Mg^{2+}	CEC	BS	TN	OC
	Mg/m^3	$CaCl_2$ (1:2)	cmol$_c$/kg				%	g/kg	g/kg	Mg/m^3	$CaCl_2$ (1:2)	cmol$_c$/kg				%	g/kg	g/kg		
	0-10 cm										10-20 cm									
1*	1.36a	4.8a	0.18c	0.35a	3.0d	1.8c	18.5a	28.8a	1.44a	25.5d	1.46b	4.6a	0.05b	0.22b	2.4d	1.6c	16.5a	25.5a	0.53b	15.2a
2*	1.24c	4.0a	0.13a	0.24b	2.1ae	1.3c	15.6a	24.0a	1.87c	22.3c	1.48b	4.1a	0.08b	0.32ab	1.3c	0.7b	11.1a	21.3a	0.73b	11.0d
3*	1.34a	3.6a	0.11a	0.31a	1.4c	0.9ab	15.9a	17.1a	1.19a	14.6ae	1.43b	3.4a	0.07b	0.24b	1.3c	0.9b	12.2a	20.2a	0.70b	8.42b
4*	1.18c	4.7a	0.10a	0.39a	2.4a	1.5ac	17.5a	25.2a	1.23a	15.6a	1.40abe	4.9a	0.06b	0.36ab	1.8b	0.9b	14.5a	21.6a	0.72b	8.68b
5*	1.21c	4.0a	0.08a	0.29a	2.1a	1.4ac	18.8a	21.0a	1.32a	16.6a	1.36abe	4.0a	0.05b	0.27ab	1.7b	0.7b	14.0a	21.2a	0.96bd	10.8d
6*	1.15d	4.5a	0.10a	0.32a	2.6a	1.3ac	17.3a	24.6a	1.87c	22.3c	1.34ae	4.4a	0.06b	0.29ab	1.9b	0.9b	13.3a	23.1a	1.27d	13.1e

*1= Uncultivated; 2= 0-5 years; 3= 5-10 years; 4= 10-15 years; 5= 15-20 years and 6= 20-25 years. ***BD**= Bulk density, **Soil texture**= Sandy loam; Means without the same letter are significantly different

Table 2 Physico-chemical properties of soils within the oil palm alleys and the reference (uncultivated) soil

No.	BD	pH	K^+	Na^+	Ca^{2+}	Mg^{2+}	CEC	BS	TN	OC	BD	pH	K^+	Na	Ca^{2+}	Mg^{2+}	CEC	BS	TN	OC
	Mg/m^3	$CaCl_2$ (1:2)	cmol$_c$/kg					%	g/kg	g/kg	Mg/m^3	$CaCl_2$ (1:2)	cmol$_c$/kg				%	g/kg	g/kg	
	0-10 cm										10-20 cm									
1*	1.36a	4.8a	0.18c	0.35a	3.0b	1.8c	18.5a	28.8a	1.44a	25.5e	1.46b	4.6a	0.05b	0.22b	2.4b	1.6ac	16.5a	25.5a	0.53a	15.2c
2*	1.24c	4.0a	0.13a	0.24b	2.1b	1.3a	15.6a	24.0a	1.87b	22.3f	1.48b	4.1a	0.08b	0.32ab	1.3a	0.7a	11.1a	21.3a	0.73b	11.02g
3*	1.36a	3.6a	0.08a	0.23b1.3a	0.7a	17.5a	13.3a	1.36a		13.7a	1.49b	3.5a	0.05b	0.27b	1.3a	0.6a	13.6a	16.9b	0.70b	6.49b
4*	1.33a	4.5a	0.11a	0.35a2.1ab	1.1a	15.8a	22.8a	1.52a		14.3a	1.44b	4.6a	0.06b	0.36ab	1.6a	1.1a	10.7a	28.8b	0.72b	6.83b
5*	1.28d	3.9a	0.10a	0.32a1.8a	0.9a	18.9a	16.6a	1.60a		16.9c	1.57e	3.5a	0.06b	0.32ab	1.4a	1.1a	14.9a	19.7b	0.88b	9.52d
6*	1.35a	3.7a	0.13a	0.38a1.7a	0.9a	16.8a	18.9a	1.37a		13.0a	1.52b	3.6a	0.06b	0.30ab	1.4a	0.7a	10.9a	21.8b	0.84b	8.68d

*1= Uncultivated; 2= 0-5 years; 3= 5-10 years; 4= 10-15 years; 5= 15-20 years and 6= 20-25 years. ***BD**= Bulk density, **Soil texture**= Sandy loam; Means without the same letter are significantly different

There was a significant drop of OC with cultivation. However, beyond 10 years it was observed that there was a build-up of OC especially in the 0-10 cm depth in both alleys and under heaped fronds except that values observed under heaped fronds were slightly higher. Beyond 20 years the OC increased sharply in soils under heaps whiles it declined in soils within the alleys. The removal of existing forest vegetation cover for oil palm produces enough biomass which not burnt is broken down by litter-feeding invertebrates such as termites, earthworms and beetles. Their actions while decreasing litter to tiny particles increases the surface for bacterial and fungal decomposition (MacKinnon et al., 1996) and account for the difference in OC values between the uncultivated and 0-5 years group. The high OC content of soils under prunings as compared to those under alleys is due to the amount, location, quality and action of temperature and moisture on the pruned material (Kirschbaum, 2000; Raich and Tufekcioglu, 2000). The trend in OC observed under prunnings was an opposite of what was seen under alleys where palm fronds heaped underwent rapid decomposition especially in the 5-10 years period to release nutrient. However, as the age of the plantation moved towards the 20-25 years period, the rate of decomposition slowed down with decomposed material being protected by overlying palm fronds. It was therefore common to find heaps of varying heights with age of the plantation. Similar observations had been made in Benin (Henson 1999).

Total N varied with amount of OM present in soils such that it increased along with changes in corresponding OM levels. However, some exceptions were associated with the uncultivated, 0-5 and the 20-25 year groups under prunnings for both depths where corresponding N contents did not appear to correspond with the high OC values observed. It is possible that part of the N present in these soils (under prunnings) were immobilised with increasing age of plantation with some being protected in the interior of soil particles (Davidson and Janssens, 2006). The C:N ratio calculated increased when increases in C were not accompanied by N additions and this change in C:N ratio had a large potential effect on processes of mineralization, immobilization (Paterson, 2003). Farmers under production systems are expected to keep C:N ratios below 12 to promote activities of soil microorganisms to release nutrients. The relatively lower C:N ratios observed for some age groups compared to the rest under alleys promoted N mineralisation and more rapid soil N turnover (Cheng et al., 1996) with the higher C:N ratios possibly slowing down microbial activity and decomposition as N becomes limiting particularly under prunings during initial periods (years) of decomposition of palm fronds. Increase in C under prunings not corresponding to increase in N especially for the 20-25 years group was partly due to different rates of decomposition of the two nutrients such that C appeared to be decomposing faster than N.

Conclusion and recommendation

The study concludes that nutrient mining in oil palm fields is possible as reduction in Ca, Mg and K were observed with continuous cultivation without replenishment. Heaping of palm fronds yielded some benefits in terms of C content with time but could not supply enough Ca, Mg and K to replace what the crops used. High temperatures hastened the rate of decomposition where nutrient release was faster than could be immediately absorbed and used by plants and were at times subject to losses associated with high precipitation. Beneficial effect of OM addition to soils was seen as prunings improved soil structure to the point that bulk density values of soils under heaps were relatively lower than those within alleys. The higher bulk densities under alleys could be attributed to human activities such as walking during harvesting and partly to the low C content of the soils. The study recommends research into how to effectively use pruned branches for compost to be applied in rings around the oil palm trees.

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Utilization of aerobically composted wood waste and chicken manure as organic fertilizer

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Summary

Poultry manure, wood shavings and sawdust were composted together under aerobic conditions for sixteen weeks. The composted samples were analyzed for nutrient content, fungi isolation and identification. Aerobic compost of 1g was diluted serially from 10^{-1} to 10^{-6} and 10^{-4}, 10^{-5} and 10^{-6} dilution were cultured on Potato Dextrose Agar (PDA). Fungi were identified by their morphological characteristics and with the use of electric photo microscope. The fungi isolated were Aspergillus flavus, Aspergillus myzae, Aspergillus candidus, Aspergillus niger, Aspergillus ustus, Penicillium camemberti, Penicillium corylophilium, Penicillium enchiopicum, Penicillium aethiopicum, Penicillium oxalicum, Eurotium herbariorum and Fusarium species. The compost composition was high in organic matter and nutrient elements which can be used to enrich the soil for maximum and sustainable crop production. The paper thus discusses the wide variety of microbes carrying out decomposition of the composting material, highlighting the role of a range of fungi. Several fungi are known to be particularly effective in decomposing woody material, such a wood shavings. It emphasizes a way of getting rid of a mixture of problem materials in an advantageous way.

Introduction

The menace caused by disposal of wood shavings and sawdust around houses, streets and major roads and by droppings from poultry houses demand means to reduce these environmental problems. This led to the idea of composting these organic wastes since composting is a means of reducing both the volume of organic waste and environmental pollution and using the material advantageously. Compost is a rich source of organic matter, which plays an important role in sustaining soil fertility. In addition to being a source of plant nutrients, it improves the physical, chemical and biological properties of the soil. Due to these improvements to the soil, crops become less vulnerable to stresses such as drought, diseases and toxicities. These advantages manifest themselves in reduced cropping risks, higher yields and lower need for the use of inorganic fertilizer by farmers (Jambhekar 2002).

Poultry manure is an organic waste material consisting of faeces and urine. Poultry manure is an excellent fertilizer material because of its high nutrient content, especially nitrogen (N), phosphorus (P) and potassium (K). Manure is decomposed in the soil and releases nutrients for crop uptake by means of a process called mineralization (Jacobs *et al.* 2003). To mineralize these organic material micro-organisms are required. Decomposition of organic waste is mediated by bacteria and fungi. Fungi are important for decomposing lignified materials, such as wood (Gautam *et al.* 2010). Dubey and Maheshwan (2005) reported that the cellulytic fungi such as *Aspergillus, Penicillum,* and *Trichodema* and *Trichurus* accelerate composting for efficient recycling of waste with high C/N ratio and reduce the composting period. It is therefore important to determine the nutrient content of composted poultry manure, wood shavings and sawdust. It is of scientific interest to identify and characterize the microbes responsible for the decomposition of the materials.

Materials and methods

Composting materials and procedures

The composting was carried out at Ambrose Alli University, Ekpoma, Edo State, Nigeria. The compost was prepared by using sawdust and wood shavings collected from sawmills, poultry manure from battery cage systems and top soil. The materials were mixed in the following ratios: 20 kg of dried sawdust and wood shavings, 10 kg of poultry manure and 3 kg of top soil. The materials were mixed with water in a basket to raise the soil water content (on a mass basis) to 50%, which is in the suitable range for micro-organisms responsible for decomposition (Wipo, 2011). Proper turning was done weekly to ensure good aeration and the process was continued for sixteen weeks. At the end of composting, a composite sample was collected for chemical laboratory analyses.

Chemical analyses

The following chemical analyses were done on the compost (to determine its value as fertilizer material): The pH was determined in water (ratio1:1, soil: water) (Bouyoucos, 1962). Organic carbon was determined by wet dichromate method (Nelson and Sommer, 1975) and available phosphorus by Bray 1 extraction method (Anderson and Ingram, 1993). Total nitrogen was determined by Kjeldahl method (Bremner and Mulvaney, 1982). Exchangeable cations (potassium, calcium and magnesium) were extracted by 1M ammonium acetate, potassium was then determined by flame photometer while calcium and magnesium were determined by atomic absorption spectrophotometer (IITA, 1979). Micronutrients such as copper, zinc, iron and manganese were also determined (Lindsay and Norvell, 1978).

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Fungi isolation and identification

Isolation

Sterilization
The culture media (Potato Dextrose Agar and saline water) and equipment used for analysis were sterilized for 15 minutes in an Autoclave at 121^{o}C.

Preparation of culture medium
To prepare the Potato Dextrose Agar (PDA) medium 16.38 g of it was dispensed into 420 ml distilled water and homogenized. This was autoclaved at 121^{o}C for 15 minutes, before adding 0.03 g chloramphenical to inhibit bacterial growth. The plates were plated in triplicate.

Procedure for isolation
An amount of 9 g sodium chloride was dispensed in 200 ml distilled water and 9 ml of the solution sterilized by Autoclave for 15 minutes at 121^{o}C and allowed to cool. Compost samples of 1g were dispensed into 10ml sodium chloride solution in test tubes, giving a 10^{-1} compost solution suspension, and serially diluted from 10^{-1} to 10^{-6}. From the 10^{-4}, 10^{-5} and 10^{-6} dilutions 1ml samples were measured into six petri dishes (that contain culture medium).

Identification

Fungi in the isolates were identified on the basis of conventional culture and morphological characteristics. Electric photo microscopy was also used for further identification, viewing the slides at 100X objective.

Results and discussion

Compost making is a simple means of improving soil fertility status and sustain crop production as well as reducing farmers dependence on mineral fertilizer. The chemical composition of compost was highly dependent on the composition of the materials used in the initial mixture, but the actual concentrations differ markedly because of the changes in the residual amount of material. The analysis of the compost showed that it was rich in mineral nutrients and organic matter (Table 1).

Table 1: Nutrient content of aerobic compost

Parameter	Units normally given as	Values
pH	-	7.65
OM	%	48.70
Total N	%	4.50
Available P	%	0.80
Exchangeable Ca	Centimol(cmol) (+)/kg Centimol (cmol)-a standard unit for expressing the concentration of cations in a comparable way	1.28
Exchangeable Mg	cmol(+)/kg	1.55
Exchangeable K	cmol(+)l/kg	1.87
Exchangeable Na	cmol(+)/kg	0.08
Extractable Mn	mg/kg	291.17
Extractable Fe	mg/kg	2,892.15
Extractable Cu	mg/kg	24.02
Extractable Zn	mg/kg	106.00

The pH of the compost was alkaline and similar results have been reported by Albaladejo et al.(2009). It therefore means that compost can be used as a source of liming to reduce soil acidity. The organic matter content of the compost was high and according to several authors, the reason for compost production is to improve the organic matter content of a degraded soil. Therefore, compost is an organic matter resource that has the ability to improve the chemical, physical, and biological characteristics of soils. According to Van Zwieten (2009) compost has a high nutrient content, especially nitrogen, phosphrous and potassium (K). It also contains micronutrients and this is confirmed by the analytical values of the compost that was prepared. According to Edward et al.(2007) a good quality compost has a significant impact in improving soil quality and crop yield.

The temperature was taken during composting and it was observed that there was an increase in temperature during the first three weeks from mesophilic to thermophilic phase and thereafter the temperature began to decrease. Gautam et al.(2011) reported a similar trend in temperature during composting. It was also observed that in order to achieve a successful composting, the influencing factors such as temperature, moisture content, aeration, pH, C/N ratio and composting mixtures should be appropriately controlled (Michel et al., 1996).

Compost prepared from the combination of two or more types of wastes enhanced fungi growth and diversity of saprophyte microorganisms that play an important role in biodegradation. Fungi isolated are discussed below: The *Aspergillus sp.* isolated were; *Aspergillus ustus, Aspergillus myzae, Aspergillus niger, Aspergillus candidus, Aspergillus flavus.* A total of six *Penicillium species were isolated: Penicillium aethiopicum, Penicillium echinulatum, Penincillium oxalium, Penicillium camemberti, Penicillium corylophilium and Penicillium funculosum.* Other fungi isolated from the compost were *Eurotium herbariorum and Fusarium species*. Storm (1985) also observed similar results, that is that the number and diversity of microorganisms are more when two or more wastes are used for composting. Rabia *et al.* (2007) have reported the highest fungi load and number of species of *Aspergillus* and *Penicillium* in compost. Giovana *et al.* (2005) also reported that *Fusarium* is found in compost and was responsible for mineralization. Despite the unnoticed role of fungi during decomposition, it is evident from this experiment that fungi, especially *Aspergillus* and *Penicillium* are important organisms during composting.

Conclusion

The compost is rich in plant nutrients and can be used to ameliorate soil for crop production. Compost is high in organic matter, nitrogen, phosphorus, potassium and other nutrient elements which makes it suitable for the improvement of soil quality and crop production. This method can be practised by local farmers to ameliorate soil for sustainable crop production. It is obvious that these agricultural waste can be composted and used as fertilizer also the fungi genera isolated from the compost were *Aspergillus, Penicillium, Fusarium* and *Eurotium.*

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Soil erodibility evaluation in Makurdi Benue state, Nigeria

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Summary

The concern over soil improvishment and erosion problems and specifically the problems associated with run-off and erosion from agricultural lands led to a combination of laboratory analysis and field simulation studies aimed at further understanding rainfall – runoff – soil –loss relationships. The erodibility of soils of sandstone and shale parent material were assessed with four indices developed in temperate countries. The indices were, " clay ratio "involving the hydrometer test (Bouyoucos, 1935), "soil aggregate stability" (Yoder, 1936), use of the "nomograph" (Wischmeier et al, 1971 and "rainfall simulation". The soils were of coarse and medium textures(sandy loam and loamy sand). Soils of the sandstone and shale parent material had clay ratio that were not appreciably different(mean of 0.88 and 0.85 respectively). Soil aggregate stability values were moderate (41 - 49%) for sandstone derived soils and low (31-36%) for shale derived soils indicating expectedly higher resistance to erosion for the sandstone compared to the shale soils. Mean values of erodibility estimates using the nomograph were 0.06 and 0.04 Mg.h.MJ^{-1}mm^{-1} for sandstone and shale soils respectively and were not significantly different. Under rainfall simulation mean soil loss value was significantly higher in the sandstone soils (10.75 kg m^{2}) compared to the shale soils (3.28 kg m^{2}). For proper soil conservation planning, indices developed in other regions of the world must be carefully tested to ensure local applicability. Intensive regional network studies re required to develop appropriate indices for modeling soil conservation in the agro ecological region.

Introduction

Soil loss is commonly predicted using the Universal Soil Loss Equation (USLE) of Wischmeier and Smith (1978) and its revised forms, the Revised Universal Soil Loss Equation (RUSLE) and the Modified Universal Soil Loss Equation (MUSLE). The equations essentially relates soil loss to the dynamic interaction of rainfall erosivity (R), soil erodibility (K), slope steepness and length (SL), cover management (C) and support practice factor (P).

Soil erodibility, a quantitative measure of the resistance of the soil to both detachment and transport, is a function of soil texture, structure, permeability, organic matter content and the management of soil (Hudson, 1995). The soil erodibility (K) factor of the USLE was defined by Renard *et al*, (1997). It may be assessed on a scale of 0 (low erodibility or high resistance to erosion) to 1, as with the clay ratio, or 0.1 for S.I unit, as with the USLE nomograph (high erodibility or low resistance to erosion) . It can be evaluated either directly using *in situ* erosion plots (Wischmeier and Smith, 1978) or indirectly (Bryan, 1968) by using the USLE nomograph (Wischmeier *et al.,* 1971) or simulated rainstorms (Dangler and EL Swaify, 1976). Assessment of soil susceptibility to erosion risk is a basis for effective conservation planning. Risk assessment requires key information on rainfall erosivity (R) and soil erodibility (K), information that is still sketchy for the Makurdi area (Isikue *et al.,* 2011). The role of soil parent material requires clearer understanding.

An investigation was carried out to assess the erodibility of soils derived from two parent materials in Makurdi using four indices.

Materials and methods

Study area

The study was carried out in Makurdi Benue state, Nigeria, located on latitude 7^{0} 41'N and longitude 08^{0} 37'E. Makurdi experiences a tropical climate, with temperatures ranging is from 22^{0}C to 36^{0}C. The relative humidity ranges from 50% to 80%. The elevation is 106.4 m. The mean annual rainfall is about 1250 mm and the duration of rainfall is between 200 and 300 days (Idoga et al.,2005). Field investigations were carried out at the University of Agriculture Makurdi's teaching and research farm as well as the student industrial work experience scheme SIWES Farm. The soils at the research farm were derived from shale and those at the SIWES farm from sandstone.

Laboratory methods

The Bouyoucos (1935) hydrometer method was used for particle size analysis of the soil. A nest of sieves was used for sand grade analysis, required for the evaluation of K with the USLE nomograph. Organic carbon was determined as described by Walkley and Black (1934). Saturated hydraulic conductivity was determined using the constant head method of Klute (1965) and Darcy's flow equation. Soil permeability was obtained from the results of the hydraulic conductivity determination as discussed by O'Neal (1952). Dry bulk density, total porosity, macro and micro porosity were calculated. Aggregate stability was determined as described by Yoder (1936). The percentages of water-stable aggregates greater than 0.5 mm diameter (excluding the sand fraction) were calculated.

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Field methods

Soil investigations in the field were carried out at four locations. Core samples were taken from these sites at 0-10 cm depth for bulk density determinations. Samples were also taken at 0 -17 cm depth with a shovel for wet sieving (aggregate stability) analysis. A portable non- pressurized rainfall simulator was constructed with dimensions of 110 cm x 210 cm (length x width) accommodating 181 drop formers. The average drop size produced was 4.6 mm. It was set to rain at an intensity of about 250 mm h^{-1} to simulate near maximum reported rainfall intensity for Makurdi (Agada, 2015). Micro- plots were constructed on a soil having a slope of about 5%. The micro-plots were 200 cm long, 150 cm wide and 30 cm deep. Water and eroded sediments were collected at the lower outlets of the plots in bins after each run. Two duplicate test runs were performed namely, dry run and wet run, each lasting for about 15 minutes, with about 150 L of water used.

Results and discussion

Table 1 gives the values of selected properties known to influence soil erodibility (Wischmeier and Mannering, 1969) for sandstone and shale derived soils. The textures were coarse to medium (sandy loam to loamy sand). Bulk densities for the shale derived soils were in the range of 1.15 g cm^{-3} to 1.35 g cm^{-3} with a mean of 1.27 g cm^{-3} and for soils of sandstone origin in the range of 1.48 g cm^{-3} to 1.6 g cm^{-3} with a mean of 1.55 g cm^{-3}

Mean erodibility values derived from clay ratios were 0.88 and 0.85 for the sandstone and shale derived soils respectively indicating no difference in the soils' resistance to erosion. Notably the clay ratio index places soils in a hierarchy of erodibility but has no defining value for "erodible" and "non erodible" soils. The percentage of water stable aggregates > 0.5 mm ranged from 32% to 36% for the shale derived soil and 41% to 49% for the sandstone derived soils. According to this parameter soils of sandstone origin (SIWES farm) were slightly more stable and thus will offer higher resistance to erosion compared to those of shale parent material. Aggregate stability governs the ease with which large aggregates above the erosion threshold can be broken down to sizes vulnerable to erosion(Bryan, 1968). Mean values of erodibility using the USLE nomograph were 0.04 and 0.06 Mg.h.MJ^{-1} mm^{-1} for the sandstone and shale soils respectively.. There was no clear difference between the two groups of soils. In the rainfall simulation study actual soil loss values were much lower for the shale derived soils than for the sandstone derived soils. Since this was the only parameter that actually measured soil loss due to erosion this must be considered to give the real difference in erodibility between the two groups of soils. Expectedly, erodibility values were lower for the wet run as compared to the dry run.

Table 1: Erodibility indices of the soils of the study sites according to different parameters

Location	Water stable Aggregates > 0.5mm (%)	Clay ratio	USLE Nomograph Mg.ha.h.$ha^{-1}MJ^{-1}mm^{-1}$	Sediment yield/ Soil loss under simulated rainfall Mg.ha.h.$ha^{-1}MJ^{-1}mm^{-1}$	
				Dry kg m^2	Wet kg m^2
SIWES farm Plot 1	49	0.89	0.071	0.707 (12)	0.55 (9.8)
SIWES farm Plot 2	41	0.87	0.041	0.62 (11)	0.57 (10.2)
Agronomyfarm Plot1	32	0.85	0.051	0.28 (5)	0.16 (2.8)
AgronomyfarmPlot 2	36	0.85	0.043	0.22 (3)	0.13 (2.3)

Conclusion

The inferred and calculated parameters did not give clear cut indications of the erodibilities of the different soils. The actual empirical measurement of soil loss done by means of rainfall simulation indicated large differences between the erodibilities of the two groups of soils. The latter is very important regarding land suitability evaluation. The study clearly indicated that indices and norms developed elsewhere cannot be used blindly in a different type of situation.

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Role of soil in nutrition sensitive food systems in Africa

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Summary

Nutrition sensitive agricultural food systems require high quality soil nutrients. This article highlights the linkages between soil and nutrition sensitive food systems. It is estimated that 95% of our food is directly or indirectly produced from soils. Nutritionally balanced soils are fundamental to sustain food systems and essential to food security and nutrition. Soil erosion and land degradation as a consequence of multiple factors result in fewer nutrients that are essential to agricultural production, food quality and nutritional value. This situation that is currently occurring across the continent has major implication not only on food quality and quantity but also increase the trend and risks of under-nutrition. Maintaining and increasing soil quality is therefore a prerequisite for reducing the risks of nutritional deficiencies in Africa.

1.0 Introduction

M.S. Swaminathan (2014) in quoting Aristotle reiterated that "soil is the stomach of the plant". Nutritious and good quality food and animal fodder can only be produced by healthy soils to guarantee food security and nutrition. In Africa micronutrient deficiencies have been reported for a range of soils under differing crop production conditions. These deficiencies can be corrected for improved soil fertility, crop yield and nutrient density of human foods. Soil fertility is important in regard to the quantity of food produced and the provision of adequate quantities of micronutrients in the diet. Central Africa for example is dominated by soils that are inherently extremely infertile and have characteristics that make soil fertility management extremely difficult. Many other parts of Africa are also dominated by very poor quality soils and unfavorable rainfall patterns; either far too high in areas like central Africa or far too low as in the 25% of Africa occupied by deserts (Laker 2005b).

Food systems include the entire range of activities, from tilling soils to consumption and re-utilization of plant and animal by-products for soil quality improvement. As part of the Food and Agriculture Organization of the United Nation's constitutional mandate to raise the levels of nutrition and standards of living of all people, food based approaches to optimize nutrition are fundamentally deployed and linked to sustainable management of natural resources, including soils. The challenge to the food system embodied in pressure on natural resources, climate change, increasing population growth, rapid urbanization, and changing lifestyles are having profound impact on food production and the daunting task of raising levels of nutrition.

The Rome Declaration of the Second International Conference on Nutrition (ICN-2) held in November 2014, jointly organized by FAO and WHO, noted with profound concern that, notwithstanding significant achievements in many countries, recent decades have seen modest and uneven progress in reducing malnutrition with the prevalence of undernourishment moderately declined, but absolute numbers remaining unacceptably high with an estimated 805 million people suffering chronically from hunger in 2012-2014 (FAO/WHO 2014). According to the 2015 Global Nutrition Report Brief on Africa the scale of malnutrition on the continent continues to be staggering with 58 million children under five stunted, 13.9 million wasted and 10.3 million overweight, while 163.6 million children and women of reproductive age are anemic; a proxy for the overall challenge of micronutrient deficiencies. Thirteen countries in Africa are faced with terrible challenges of managing the levels of under 5 stunting or anemia in women of reproductive age (Africa Brief - GNR 2015). Approximately one person out of four in Sub-Saharan Africa is estimated to be undernourished in 2015 compared to a ratio of one out of three in the early 1990s (FAO, 2015). The region is affected by the multiple burden of malnutrition with coexistence of several forms of malnutrition.

2.0 The value of fertile soils to sustainable nutrition sensitive food systems

Food crops grown on fertile soils contain more micronutrients than nutrient-stressed crops grown on infertile soils. Soil micronutrient status, cropping systems, variety selection (i.e., plant breeding) for micronutrient-dense crops (e.g., bio-fortification) and soil fertilization practices are important factors that impact the nutrient output of food systems. Soil improvements increase productivity and allow for greater diversity of crops. Sustainable soil management is therefore critical for the production of nutritious food. In addition to sustaining directly or indirectly 95 percent of food production, soils host more than a quarter of the planet's biodiversity and play a critical role in the carbon cycle (FAO 2015). At the same time, the level of soil degradation – estimated at 33 percent globally – is "alarming" (FAO 2015). A shortage of any one of the 15 nutrients required for plant growth in soils can limit crop yield and affect the nutritional value of food. By 2050, agricultural production must increase by 60% globally – and by almost 100% in developing countries, particularly in Africa, in order to meet food demand. Sustainable soil management could increase production by up to 58 percent more food (Wall & Six, 2015).

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In the case of zinc, a micronutrient essential for growth and maintenance or gene expression, tolerance to environmental stress conditions results in higher requirements of Zn to protect cells from the detrimental effects of stress. This micronutrient deficiency appears to be the most widespread and frequent in crop and pasture plants worldwide, resulting in severe losses in yield and nutritional quality. This is particularly the case in areas of cereal production. It is estimated that nearly half the soils on which cereals are grown have levels of available Zn low enough to cause Zn deficiency (Alloway, 2008). Zinc deficiency in soils can be absolute or induced. Absolute deficiency is related to the parent material, texture, degree of weathering and/or pH and calcareousness of a soil. Induced deficiency is mainly due to injudicious liming, injudicious phosphorus fertilization or removal of topsoil (Laker 2005a).

Since cereal grains have inherently low bio-available Zn concentrations and growing them on potentially Zn-deficient soils further decreases grain Zn concentration (Cakmak 2007). Well -documented Zn deficiency problems in humans occur predominantly in the African regions where soils are low in available Zn and cereals, root and tubers are the major source of calorie intake (Laker 2005a). Zinc-deficient soils may remain undetected for many years unless soil or plant diagnostic tests are carried out, because there are no obvious early signs of stress in the crops growing on them (Alloway, 2008).

3.0 Maintaining good soil quality to sustain biodiversity and optimal nutritional value

The consciousness of human beings to their utter dependence on soils and the implication of soil degradation to their nutritional survival impel them to adapt to mitigate the negative effects of climate and environmental conditions to soil quality and fertility. In re-configuring the sustainable value of soils, there is increasing advocacy for agro-ecology; organic farming, conservation agriculture with zero tillage to ensure the natural balance of soil nutrient fertility with soil microorganism and fauna, agro-forestry eco-systems for crops, trees and animal production, resulting in the sustainable management of soils to produce more diversified and healthy nutritious foods. Faster bio-organic decomposition and biomass soil growth would create much more fertile soils, which will lead to increase in crop yield and outputs of nutrient dense or bio-fortified crops being promoted in Africa.

The diversity of species used for food has diminished drastically over the years and most people now depend on three main cereals, namely maize, rice and wheat, which combined provide over 50% of the global food energy intake and with only 12 other crops and animal species altogether providing over 75% of the world's food today (FAO, 2012). The nutritional quality of food is highly compromised with increasing trends in high consumption of sugar, salt and ultra-processed fat coupled with low physical activity, micronutrient deficiencies, linked to poor quality nutrient deficient soils and the multiple burden of malnutrition.

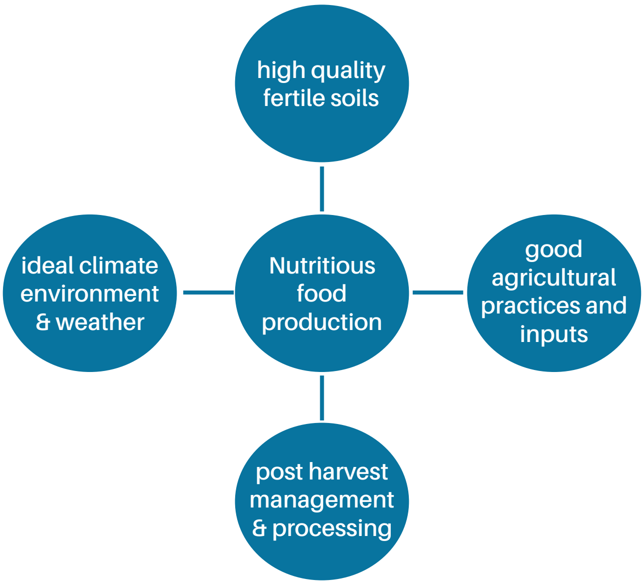

Figure 1: *Elements linked to sustainable nutritious food production*

Whereas various studies have consistently associated increasing dietary diversity to micronutrient density of the diet both in infants and women using indigenous foods, most indigenous foods are now being underutilized or inaccessible due to reducing biodiversity and soil degradation. Nutrition sensitive agricultural food systems therefore require high quality soils for producing and ensuring dietary diversity in combination with appropriate care practices, water and sanitation for good nutrition and health. This aligns directly with the second SDG of linking food systems and sustainable agriculture through food-based approaches to nutrition.

4.0 Conclusion and international action for nutritionally sustainable food and soil systems

The Rome Declaration of the ICN-2 recognizes the need to address the impacts of climate change and other environmental factors on food security and nutrition, in particular on the quantity, quality and diversity of food produced and taking appropriate action to tackle their negative effects, particularly on soil fertility. It also acknowledges that current food systems are being increasingly challenged to provide adequate, safe, diversified and nutrient rich food for all that contribute to healthy diets due to, *inter alia*, constraints posed by resource scarcity and environmental degradation, as well as by unsustainable production and consumption patterns, food losses or waste, and unbalanced distribution (FAO/WHO 2014). Recommendations 10 and 12 of the framework for action of the Rome Declaration therefore seeks to promote the diversification of crops, including underutilized traditional crops, more cultivation of fruit and vegetables, and appropriate production of animal-source foods while applying sustainable food production and natural resource management practices including effective soil management to enhance the resilience of the food supply system, including areas affected by climate change (FAO/WHO 2014).

In taking international action, concrete steps are required to characterize and manage land areas for fertile soils capable of sustaining two to three good crops a year; declared as Special Agricultural Zones (SAZ) with soil health monitoring and amelioration centers. These centers could assist farmers with soil health cards with extension services on good farming practices and assistance to rectify soil defects, such as salinity, alkalinity and water logging challenges. Special attention could be paid to soil organic matter since this is essential for improving the micronutrient content, hydraulic conductivity, chemistry and microbiology of the soil. There is the need to popularize local level soil health assessment systems such as the presence of earthworms and nitrogen fixing and phosphorus solubilizing microorganisms. These could be coupled with local level soil health managers to support both soil health monitoring and nutrient amelioration. If we do not attend to soil nutritional value and improvement, we will not be able to achieve human nutritional value and therefore the goal of ending hunger and malnutrition in Africa by 2025.

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The importance of sustainable land management for food security and healthy human nutrition in central Africa

Ousseynou Ndoye[1]

Introduction

Among the overarching objectives of governments in Central Africa, poverty reduction, food security and nutrition are very important goals. This is confirmed by the fact that countries in Central Africa have defined poverty reduction strategies. Furthermore, in June 2014, an important meeting of the African Union (AU) on food security and nutrition was held in Malabo, Equatorial Guinea and African leaders and their international allies such as The Food and Agriculture Organization of the United Nations (FAO), The United Nations Development Program (UNDP), The World Bank (WB) made important decisions for the future of the continent. In May 2013, FAO organized an international conference on forests for food security and nutrition which was widely attended. In November 2014, FAO and The World Health Organization (WHO) organized another international conference on nutrition, which showed the continuous commitment of the organizations to fight poverty and hunger. At the regional level, the Forestry Commission of Central Africa (COMIFAC) has elaborated in 2013 a program on forests for food security and nutrition in Central Africa. In September 2015, in Durban in South Africa, the issue of food security and the role forests and trees can play stood out very strongly in the agenda and in the discussions in plenary and parallel sessions. Under this context, sustainable land management has an important role to play in achieving food security and nutrition.

It is argued in this paper that to reconcile land management and food security, governments of Central Africa should allocate more forests to local communities' management to improve their food security and to increase investment in agricultural and forestry research aimed at producing improved varieties of agricultural and forest products which will allow farmers to stay longer in a given piece of land without having yield losses.

The second section of the paper discusses the dimensions of food security. Section 3 discusses food security and sustainable land management. The implications of land management for food security are discussed in section four. The last section provides few concluding remarks.

Dimensions of food security

Food security is assured when all individuals at all times have economic, social and physical access to enough food, which satisfy their nutritional requirements and food preferences for an active and healthy life (FAO, 2014). Food security has four pillars: availability, access, utilization and stability. According to the definition, the nutritional aspect is embedded in the concept of food security. Food security has both supply and demand dimensions. Supply relates to the provision of agricultural and forest products after harvesting of crops or collection from forests for direct home consumption. The demand side refers to the need for agricultural and forest products to be marketed and to purchase food from the revenues received. Another dimension of supply relates to the direct use of medicinal plants to improve human health and thus increase labour productivity in agriculture. This shows the complementarity between agriculture and forest at the household level (Ndoye and Asseng Ze, 2015). For example, in the Senanga district of Zambia, as study by Kwaw-Mensah (1996) showed that farmers rated poor human health as the most important factor responsible for low agricultural productivity in the district.

At the macro level it should inspire and motivate intersectoral collaboration between ministries in charge of agriculture and those in charge of forests and the environment.

Sustainable land management and food security

Sustainable land management is very important in achieving food security and efficient nutrition. This is because the supply and the demand sides of the food security equation need to be balanced by means of appropriate land use arrangements: primary forest, secondary forest; fallows, home gardens, agricultural land, forest concessions, community forests, and communal forests. Furthermore, improved infrastructure (roads and transport services) is required to enable efficient movement of forest and agricultural products to markets where buyers purchase the products they want to consume while sellers dispose of their products to get revenues, which will enable them to purchase other food items. Markets which facilitate these transactions are located in rural, semi-urban and urban areas.

Tenure security is very important in strengthening the relationship between sustainable land management, appropriate land use and food security. When actors feel secure in their ownership of land and forests, they will be willing to provide additional investments in those resources. This can facilitate reforestation of degraded land with trees of economic values; it also facilitates the adoption of agroforestry technologies (domestication) and more planting of trees in the agricultural landscape.

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Implications of land management for food security in central Africa

Central Africa is in this paper defined as consisting of the countries indicated in Table 1. It is home of the second largest contiguous forest in the world after the Amazonia, and for that reason it is an important reservoir of biological diversity. Around 70 million persons exploit these resources to satisfy their subsistence needs, income generation and employment. Non Wood Forest Products (NWFP), which are a major component of the biological diversity, are edible and medicinal plants, bush meat, insects, honey, rattan and other fibres for building shelter or tools. In addition, the forests of Central Africa provide ecosystem services, including biodiversity protection, and they possess great cultural, religious and aesthetic values for the people of the region. Therefore, the well-being of rural people is affected by all forms of development that impact the forests.

Forest is allocated for timber exploitation, for agricultural production (slash and burn agriculture, industrial plantations, livestock, fisheries and aquaculture), community forestry exploitation, mining, infrastructure development, and biodiversity conservation (protected areas). In forest concessions, traditional hunting and the collection of NWFP are authorized to enhance food security and nutrition of rural populations. These efforts made by timber companies are extremely important but they are not enough if the Forestry Commission of Central Africa (COMIFAC) sub regional guidelines on NWFP are to be implemented. These guidelines recommend the adoption of commercial use rights for NWFP that are not threatened. It means that in addition to using NWFP for home consumption, the commercial use right allows communities to sell or exchange NWFP that are not threatened.

Table 1 shows that the area under protected areas differs widely between different countries in Central Africa. In COMIFAC countries, the lowest percentage of national territory devoted to protected area management is found in Burundi (5.14%) while the maximum is found in Sao Tome and Principe (29.47%).

Table 1. *Percentage of the territory allocated to protected areas in different Central African countries*

Country	Area in protection (km^2)	Area in protection as % of total territory
Burundi	1433	5.14
Cameroon	38250	8.05
Central African Republic	70145	11.25
Congo	39924	11.67
DRC	264157	11.26
Gabon	34595	11.91
Equatorial Guinea	5910	21.11
Rwanda	2354	8.93
Sao Tome and Principe	295	29.47
Chad	113678	8.85

Source: *RAPAC/OFAC/COMIFAC 2015*

In protected areas, rural communities are not allowed to enter and collect forest products. In Burundi, despite the protection of parks and reserves, women and other indigenous population members enter the reserves illegally to get forest products for their survival needs. If they are caught, they are beaten by forest eco-guards or put in jail. Food security and nutrition are threatened under these conditions. In principle, the policy guiding the management of protected areas is the same in other countries of Central Africa. Protecting forest biodiversity is important and should always be a major goal that needs to be pursued to reduce green-house emissions, and to sequester more carbon and reduce the negative effect of climate change. However, human beings should be put in the fore front within the forest landscape of Central Africa, especially in a region where there is acute poverty and serious development challenges (FAO, 2015).

Mining activities are also getting more important in Central Africa. One issue that needs more attention is the superposition of areas allocated for mining and those allocated to timber exploitation or between areas allocated for protection and those allocated for mining (Oyono et al., 2013). A conflict arises between the short term creation of job opportunities and income from timber exploitation and mining activities on the one hand and the long term negative impacts, often irreversible, that these have on food security and nutrition and the environment. Policy makers in Central Africa need to address this problem in countries where these conflicts are likely to take place.

Another development since 2007 is land grabbing which has become an important issue in Africa. It is a lease between 30 to 99 years or a transfer of land ownership to foreign investors facilitated by the government. In the Democratic Republic of Congo, 3 million hectares of land were granted to China for the production of biofuels when the country has 71 percent of its population being food insecure and where only 7 million hectares are currently cultivated (Laker, 2013). Furthermore, importing food is expensive due to bad or inexistent roads *(http://www.grain.org/article/entries/4575-land-grabbing-and-food-sovereignty-in-west-and-central-africa)*. In Cameroon, in 2006, 10000 hectares on a 99 year lease were given to a subsidiary of the Shaanxi Land Reclamation General Corporation (http://www.grain.org/article/entries/4575-land-grabbing-and-food-sovereignty-in-west-and-central-africa). In Congo, South African groups obtained 80000 hectares from the government under a 30-year lease to grow rice, corn and soybean. Furthermore, a concession of 470000 hectares was granted to a Malaysian company to produce oil palm causing lot of damages to local livelihoods (https://www.grain.org/article/entries/4575-land-grabbing-and-food-sovereignty-in-west-and-central-africa). Fortunately, there are examples in Madagascar, Ethiopia and Uganda where local communities did not accept to be dispossessed with their customary rights and successfully opposed it .

Community forestry has also grown in importance in Central Africa, especially in Cameroon, Gabon and Democratic Republic of Congo (Karsenty et al., 2010). They provide an opportunity to village associations to legally harvest, process and trade timber (Lescuyer et al., 2015) in order to improve their livelihood and food security. Most of the current focus is on timber, although there is a need to include the exploitation of NWFP as an option to diversity the livelihood opportunities of communities. COMIFAC has recently organized a regional meeting which recommended a better inclusion of economic and social particularities of community forestry in the legal framework of countries in Central Africa (COMIFAC, 2015).

With a growing population in Central Africa, there is increasing pressure for land use expansion, but at the expense of the forest which will not be sustainable. The following actions are therefore needed to reconcile sustainable land management and food security and nutrition in Central Africa:

- There is a need for more investment in agricultural research (crops, forestry). This will promote the availability of high yielding adapted cultivars of crops and forest products which will adapt to climate change. The governments of countries in Central Africa have an important role to play by honouring the allocation of 10 percent of the countries' budget for agriculture as committed in 2003 in Maputo (Mwape, 2009).

- Appropriate innovative agricultural practices, resulting from technological breakthroughs from agricultural and forestry research, should be developed and implemented in rural areas. For example, it will be good to readjust the agricultural calendar to cope with the development of new improved cultivars. The periods for timely planting, weeding and harvesting should be communicated to farmers in order to enable them to maximize their production.

- Governments of Central Africa should increase the area of forests allocated to community management. This will improve the livelihood and revenues of men, women, youth and indigenous communities.

- Tenure policy is very important in Central Africa. There is a need to ensure that local communities have secure access to forest resources by paying particular attention to women. For that reason the adoption of the FAO voluntary guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the context of National Food Security needs to be implemented by countries in Central Africa.

Conclusion

As shown in the paper, sustainable land management is very important to strengthen food security and nutrition in Central Africa. Policy makers have a crucial role to play at a moment where the expenditures on food imports are affecting heavily the terms of trade of countries in Central Africa. For that reason, more investments in agricultural and forestry research are needed to reverse this trend for the well- being of the population and the environment.

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Human impacts on sustainable land management in game parks: findings based on research in the Kruger national park, South Africa, and reconnaissance studies in Serengeti national park, Tanzania.

Gerhard Nortjé[1]

Summary

There is no doubt that food security is under threat in Africa and the world today. There is also much saying going around that Africa can feed the world. But is this true within the background of the vulnerability and low resilience (recovery potential) of much of Africa's soil resources to human impact? Vulnerability to human impacts and low resilience are especially true regarding the soils of southern Africa and specifically South Africa. It is said that if the world is in environmental extremes today it is more through the rapid physical and chemical changes to our soils and the rapidly changing of our air and water. The rapid rate at which our surface soil is being lost by erosion, surface crusting and sub-soil compaction is a major threat to our very existence.

Introduction

Soil is a non-renewable (finite) resource, meaning its loss and degradation is not recoverable within a human lifespan. As a core component of land resources, agricultural development and ecological sustainability, it is the basis for food, feed, fuel and fibre production, and for many critical ecosystem services. Soil is, therefore, a highly valuable natural resource, yet it is often overlooked. The natural area of productive soils is limited – it is under increasing pressure of intensification and competing uses for cropping, forestry, pasture / rangeland and urbanization, and to satisfy demands of the growing population for food and energy production and raw materials extraction (Laker, 2005). Soils need to be recognized and valued for their productive capacities as well as their contribution to food security and the maintenance of key ecosystem services.

Soil degradation is caused by unsustainable land uses and management practices. About 33% of land in the world is moderately to highly degraded due to erosion, salinization, compaction, acidification and chemical pollution of soils. The current rate of soil degradation threatens the capacity of future generations to meet their most basic needs. There is little opportunity for expansion in the agricultural area in the world, except in some parts of Africa and South America (Laker, 2005). Much of the additional available land is not suitable for agriculture, and the ecological, social and economic costs of bringing it into production will be very high. South Africa's soil resources are highly susceptible to sub-soil compaction and crusting (Laker, 2005). They also are characterized by low resilience (recovery potential). This means that even small mistakes in land use planning and land management can be disturbing, with little chance of recovery once the degradation has been caused. Sustainable management of the world's agricultural as well as rangeland soils and sustainable production have, therefore, become imperative for reversing the trend of soil degradation and ensuring current and future global food security.

With regards to human impacts on our soil resources, it is not just management for agricultural production, that is important, but also recreational impacts on our soils in protected areas. Recreational off-road driving (ORD) is on the increase in protected areas in Africa (Nortjé, 2014). The main reason for recreation in protected areas is to increase revenue through ecotourism for conservation (Nortjé *et al*, 2012). But these activities have serious long-term detrimental impacts on sub-soil compaction, surface crusting and vegetation (grass) recovery (Nortjé *et al*, 2012).

The impacts of ORD in Africa have been studied by, amongst others, Nortjé (2014), Bhandari (1998), Onyeanusi (1986) and Daneel (1992). ORD has been practised in the Masai Mara Reserve, in Kenya, and the Serengeti National Park (SNP), in Tanzania, for a long time (Bhandari, 1998; Onyanusi, 1986), but was only recently (2001) officially introduced in the Kruger National Park (KNP), in South Africa (Nortjé, 2014).

Discussion and conclusions

A recent visit to the SNP was a dream come true. Everything one reads and sees of the Serengeti is true. This is the KNP, only on a much larger scale, without fences and telephone lines. One easily sees hundreds of thousands of wildebeest on a game drive of three hours (Figure 1). The section of the park that was visited, one would describe as grassland savannah - vast grasslands, dotted here and there with thorn trees (Figure 2) and granite inselbergs (Figure 3).

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Figure 1: Wildebeest on the Serengeti plains

Figure 2: Thorn trees on the plains

Figure 3: Granite inselbergs

The soils in the Serengeti are characterized by extremely unstable 'Solonetz' soils in the valley floors- the Estcourt soil form in South Africa. The gigantic prisms are striking (Figure 4). These soils are naturally extremely susceptible to degradation due to human activities, such as overgrazing by Masai cattle (Figure 5) and ORD (Figure 6). Apparently, the large migratory herds of wildebeest are not the cause of the overgrazing problems. They migrate in a circle pattern, thus causing a typical pressure grazing scenario (non-selective pressure grazing) for a very short time, followed by long enough recovery time. Selective grazing by Masai cattle causes the problem.

Figure 4: Escourt soil form - S.A. (Solonetz - WRB), with large prisms visible

Figure 5: Soil and vegetation degradation because of Masai cattle overgrazing

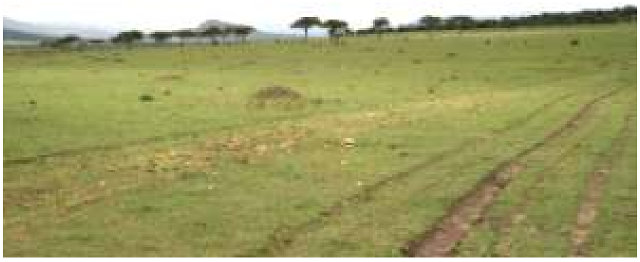

Figure 6: Soil degradation because of recreational off-road driving (ORD).

Recommendations and suggestions

It is very important to manage soils in Africa for agricultural, rangeland and conservation purposes sustainable. In order to do this, what is required is proper land use planning and in which soil surveying and land suitability assessments should play a major role. Delineation of soils with regards to appropriate sustainable land uses and management is also in protected areas are very important, just like for agricultural and other land uses. ORD has been proven to be an ecologically non-sustainable practise and should, if possible, not be allowed on any land. If it is not possible to totally stop ORD, the following recommendation should be followed:

- Eliminate bare soil: manage the protected area in such way as to never allow overgrazing or unnecessary ORD;
- Controlled traffic: fewer vehicle passes caused less compaction than more vehicle passes on the same tracks, but most compaction occurred during the first pass. Thus, driving in the same tracks more than once is less damaging than driving once on different tracks. 'Controlled traffic' could solve this problem and should be considered when developing management strategies for ORD in wildlife protected areas;
- Design/re-design better planned road networks according to a soil sensitivity map: this could allow excellent animal sightings, without the necessity to drive off-road;
- Lower tyre pressures should be considered when driving off-road for any purpose. No driving on wet soil should be considered, although it has been proven that any vehicle driving off-road also cause soil compaction on dry soils;
- The following areas should be avoided at all costs: Ramsar pans, Vlei areas, Soils with Prismatutanic B-horizons (so-called 'sodic' sites), Silt-loam soils and soils with high fine sand + silt contents, Sandy soils with less than 15% clay content, Barren areas with no grass cover.

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A meta- analysis of climate change mitigation potential of trees/forest, afforestation and woody perennials through soil carbon sequestration in Africa

Oladele O. Idowu[1] *and Ademola K. Braimoh*[2]

Summary

This paper presents the results of a meta- analysis of climate change mitigation potentials of trees/forest, afforestation and woody perennials through soil carbon sequestration in Africa. A review of the scientific literature on soil carbon sequestration in Africa was carried out to assess the greenhouse gas mitigation potential of different agricultural land management activities using on-line scholarly and scientific databases as well as more general search engines such as Google. Estimates of the meta-analysis of soil carbon sequestration rates were converted to net climate mitigation benefits (abatement rates) by converting the C sequestration rates to carbon dioxide equivalent and adjusting for emissions associated with the land management technologies. The results show that woody perennials have the highest climate change mitigation potential with 4.99and 7.53tCO_2eha^{-1} yr^{-1} respectively. This is followed by the trees/forest 6.69tCO_2eha^{-1} yr^{-1}.

Introduction

Africa, the second largest continent, has a wide diversity of climates, ecosystems and soil conditions (FAO, 2005). Farming systems in Africa have been evolving towards land-use intensification in response to population growth and the scarcity of land suitable for long-fallow shifting cultivation. Input intensification will be increasingly important in densely populated areas. Evidence suggests that heavy investments in soil fertility restoration will be required to create the conditions for profitable and sustainable intensification (Tittonell and Giller, 2013). According to UNEP's report on Global Assessment of Human-Induced Soil Degradation (GLASOD) some 494 million ha soil has been degraded in Africa, due mainly to deforestation, overgrazing, agricultural mismanagement, and over exploitation (Oldeman et al., 1991). Overgrazing (49%) and agricultural mismanagement (24%), together 73% (nearly three quarters) are the main causes of soil degradation in Africa. Water erosion (46%) and wind erosion (38%), together 84%, are the main types of soil degradation in Africa. These degraded systems should be managed judiciously and appropriately to reduce carbon emissions and increase carbon sinks in vegetation and soil, thus contributing to global climate change mitigation (WBBGU, 1998). The Green House Gas (GHG) mitigation potential of Sustainable Land Management (SLM) in agricultural lands is very large (Liniger, et al 2011, Kaczan, Arslan and Lipper 2013, Branca, McCarthy, Lipper and Jolejole 2011), but if not managed judiciously and appropriately can have major negative impacts that may outweigh the benefits from carbon sequestration. In humid tropical zones of Africa, retaining shade and understory trees in cacao, for example, can provide vast carbon stores. Mature cacao agroforestry systems in Cameroon store 565 tons of CO_2eq per hectare in the soil. Even in semi-arid lands, agroforestry systems such as intercropping and silvo-pastoral systems, with 50 trees per hectare, can store 110 to 147 tons of CO_2eq per hectare in the soil alone (Liniger, et al 2011). Forest and plantation ecosystems management practices can play a significant role in climate change mitigation by sequestering carbon through photosynthesis (Strassburg et al., 2009; Guariguata et al., 2008); However, in South Africa the main impact of forest plantations, planted in the higher rainfall upper parts of catchments, is to drastically reduce the amount of runoff. In some cases perennial rivers become seasonal rivers. This has serious implications for communities, towns, farmers, industries, conservation areas in drier areas downstream which/who are dependent on the runoff from these areas. Afforestation also increases the soil erosion hazard and leads to soil physical degradation in the form of soil compaction (Department of Environmental Affairs and Tourism 2006). The focus of this paper is on soil carbon sequestered from different land management practices associated with trees/forest, afforestation and woody perennials. This is predicated on the fact that the IPCC (2007) stated that a large proportion of the mitigation potential of agriculture (excluding bio-energy) arises from soil carbon sequestration, which has strong synergies with sustainable agriculture and generally reduces vulnerability to climate change. Soil carbon sequestration, according to the IPCC's scientific advisors on land use, represents 89% of agriculture's greenhouse gas mitigation potential. However, important decisions on agricultural and climate policy are being made without consideration for 89% of agriculture's greenhouse gas mitigation potential (Soil Association 2009). FAO (2009) reported that overlaying FAO Carbon-Gap and Hunger Maps, which respectively show (i) soils lacking carbon ("carbon-gaps") and (ii) the geographic incidence of hunger, reveals that countries or regions with large food insecure populations often also have large "carbon-gaps," which result in low-yield production and may increase climate vulnerability. A number of agricultural management practices, including those employed in organic and conservation agriculture capture carbon from the atmosphere and store it in agricultural soils. These practices involve increasing the organic matter in soils, of which carbon is a main component. This, in turn, increases fertility, water retention and the structure of soils, leading to better yields and greater resilience.

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Soil Science Society of America (SSSA, 2001) recognizes that C is sequestered in soils in two ways: direct and indirect "Direct soil C sequestration occurs by inorganic chemical reactions that convert CO_2 into soil inorganic C compounds such as calcium and magnesium carbonates." Indirect plant C sequestration occurs as plants photosynthesize atmospheric CO_2 into plant biomass. Some of this plant biomass is indirectly sequestered as SOC during decomposition processes. The amount of C sequestered at a site reflects the long-term balance between C uptake and release mechanisms. Because those flux rates are large, changes such as shifts in land cover and/or land-use practices that affect pools and fluxes of SOC have large implications for the C cycle and the earth's climate system. Different ways and mechanisms to mitigate climate change include either reducing GHG emissions or by capture or sequestration of C in aboveground biomass or soils. Soil C sequestration - often with a focus on agricultural soils - has been repeatedly proposed as a promising way out of the dilemma (Lal, 2002, 2011). The argument quite often relies on the magnitude of C stored in soils as well as the vast land area coverage of soils. Agricultural soils occupy 37% of the earth's surface. The C found in the upper 1m of soils is estimated to about 2000e2500 Gt, whereas about 60% of this is organic (SOC) and about 40% inorganic (Sommer and De Pauw, 2011). Thus, the amount of C in soils is for instance approximately three times higher than the amount of C bound in the aboveground biomass, and at least 230 times higher than the 2009-global anthropogenic CO_2 emissions. So, the argument is that small positive changes in the global SOC pool could have a major impact, or in other words, soils could be major sinks of the GHG carbon dioxide. This argument is captured within the carbon wedge framework of Pacala and Socolow (2004) in which 'adoption of conservation tillage in all agricultural soils worldwide', is included as a component of the carbon wedge 'natural sinks'.

Soil is central to most SLM technologies because it is the basic resource for land use. It supports all the terrestrial ecosystems that cycle much of the atmospheric and terrestrial carbon. It also provides the biogeochemical linkage between other major carbon reservoirs, namely the biosphere, atmosphere, and hydrosphere. Soil carbon has a strong correlation with soil quality, defined as the ability of soils to function in natural and managed ecosystems. Soil carbon influences five major functions of the soil (Larson and Pierce 1991), namely the ability to accept, hold, and release nutrients; accept, hold, and release water both for plants and for surface and groundwater recharge; promote and sustain root growth; maintain suitable biotic habitat; and respond to management and resist degradation. Increasing soil organic carbon can reverse soil fertility deterioration, the fundamental cause of declining crop productivity in developing countries.

Sustainable land management provides carbon benefits through three key processes, namely carbon conservation, reduced emissions, and carbon sequestration. Many natural land systems such as native forests, grasslands, and wetlands have relatively high carbon stocks. Conserving this terrestrial carbon pool accumulated over millennia should be a major priority, as it offers the greatest least-cost opportunity for climate mitigation and ecosystem resilience. Zero tolerance for soil erosion is indispensable for soil carbon conservation. Removal of the vegetation cover aggravates losses by soil erosion and increases the rate of decomposition due to changes in soil moisture and temperature regimes. Because soil organic matter is concentrated on the soil surface, accelerated soil erosion leads to progressive depletion of soil carbon. Bush (tree) encroachment into savannah and grassland areas can increase carbon sequestration, but enhances soil erosion, especially sheet erosion of the fertile topsoil with the highest SOM levels in the profile. The latter may outweigh the former (Eldridge, et al 2011).

Methods

A review of the scientific literature on soil carbon sequestration in Africa was carried out to assess the greenhouse gas mitigation potential of trees/forest, afforestation and woody perennials (such as coffee / cocoa plantations, fruit orchards, and trees) activities using on-line scholarly and scientific databases as well as more general search engines such as Google. Due to paucity of such research in Africa, all possible retrievable publications in scientific journals and reports were considered. Most of the review covers carbon sequestration and modeled values or estimates as published. Estimates of soil carbon sequestration rates were converted to net climate mitigation benefits (abatement rates) by converting the C sequestration rates to carbon dioxide equivalent and adjusting for emissions associated with the land management technologies (Eagle, et al 2010). The analysis considered the fact that most studies reported concentrations of carbon in soil samples (Cc in g kg-l). These were converted to volumes and then areas to calculate stocks (Cs in kg-' ha-1) and sequestration rates (kg ha-' yr-l) using bulk density (BD, in g crrr-) and sample soil depth (0, in cm)

$$Cs = BD \times Cc \times D \times 10{,}000$$

In a few studies, value was given in terms of percent soil organic matter. In these cases, concentrations of Cc (g kg-l) were calculated as

$$Cc = 0.58 \times OM\% \times 10$$

In some cases, only a single value, either initial or average across treatments, was provided for bulk density. In these cases, that value was assumed to apply to all treatments. If no bulk density information was provided in a paper (or other reports about the same study cited by that paper), then bulk density was estimated using known pedotransfer functions (that is, simple regression equations) developed for that region or extracted from the International Soil Reference Information Center–derived soil properties database (www.isric.org).

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Results and discussion

Table 1 presents the summary of observed rates of soil carbon sequestration for trees/forest, afforestation and woody perennials covered in this review. From Table 1, the practice of keeping trees on the field and the use of forest based farming (Taungya system) sequestered an average of 1204 kg C $ha^{-1}yr^{-1}$. Agroforestry has the potential to sequester significant amounts of carbon for 2 reasons. First, the area currently in crops and pastoral systems is large. Second, although the density of carbon storage is low in comparison with forests, the woody biomass of agroforestry systems could provide a source of local fuel. This fuel would reduce pressure on the remaining forests in the area and, at the same time, provide a substitute for fossil fuel. These effects are important because the most effective way to use land for stabilization of atmospheric carbon is through the combination of reforestation and substitution of wood fuel for fossil fuel (Hall et al. 1991). Takimoto et al (2008) reported that F. albida parklands, stored more C than improved agroforestry systems (live fence and fodder bank) or abandoned land. Similarly Garrity (2010) indicated that the carbon sequestration potential of agroforestry systems varies greatly from under 100Mt to over 2000Mt of carbon dioxide equivalent per year particularly the use of Faidherbia albida, in Malawi and Niger. The biophysical and spatial potential for carbon sequestration in Africa is high but the socio-political conditions related to land usage, ownership and permitted land management practices are not, constituting a serious dilemma for carbon storage on the continent—and a similar dilemma for biofuel projects. The prevailing land tenure practices in Africa will influence how afforestation and reforestation will improve soil carbon sequestration. Kauppi and Sedjo, (2001) recommended the development and implementation of Western notions of property rights, along with improved governance, local participation, and sustainable development in order to overcome the limitations of land tenure in afforestation and reforestation land management practices.

Afforestation recorded a mean carbon sequestration of 1163kg C $ha^{-1}yr^{-1}$; while for grazing land and cropping intensity had 799 and 896 carbon sequestration kg C $ha^{-1}yr^{-1}$ respectively. Lal, (2004) noted that afforestation, the establishment of tree plantations has a large potential for SOC sequestration in the tropics. Deans et al. (1999) reported that in dry savannahs SOC accumulation under 18-year plantation of acacia senegal in northern Senegal at the rate of 0.03%/yr under the tree canopy and 0.02%/yr in the open ground, corresponding to SOC sequestration rates of 420 and 280 kg C/ha/yr for a soil bulk density of 1.4 Mg/m3. Johnson (1992) reported a > 35% increase in soil C following the afforestation and reforestation of cultivated soils.

In this review, 44 estimates on the use of woody perennials such as cacao plantation in Ghana and Cameroon, coffee plantation in Burkina Faso, indigenous fruit trees in South Africa, oil palm plantation in Côte d'Ivoire, exotic tree species in Ethiopia, rubber plantation in Nigeria and Ghana, cashew and teak plantation in Nigeria were covered. The average carbon sequestered from woody perennials was 2303 kg C $ha^{-1}yr^{-1}$ (Table 1). Ofori-Frimpong et al (2010) stated that cacao planted at low plant density and under shade stores more carbon per unit area of soil than an equivalent area of cacao planted at high density without shade. In addition to C sequestration in biomass and soil, tropical plantations are needed for timber, and more importantly, as fuel wood for cooking. In western Nigeria, Ekanade et al. (1991) reported that the SOC pool under forest was 29 g/kg and that under cacao was 19 g/kg. Similar observations were made by Adejuwon and Ekanade (1988) in Oyo state, Nigeria. Also in southern Nigeria, Ogunkunle and Eghaghara (1992) observed that the SOC concentration under 10-year old cacao plantation was 25 g/kg compared with 35 g/kg under forest. In Nigeria, Aweto (1987) reported that the SOC concentration was 14 g/kg under primary forest and 12 g/kg under a 18-year old rubber plantation. The SOC concentration under rubber increased over time. In Kade, Ghana, Duah- Yentumi et al. (1998) reported that the SOC concentration of a soil under 40-year old rubber plantation was lower than that under virgin forest or 20-year old cacao. Both rubber and cacao received neither fertilizer nor manure. The high variability in the minimum and maximum amount of carbon sequestered by trees/forest, afforestation and woody perennials land management practices could be attributed to the intervening variables and different interaction such as soil conditions, vegetation cover, temperature, amount of precipitation, soil types among others in the sites where data were collected

Table 1: Summary of observed rates of soil carbon sequestration by trees/forest, afforestation and woody perennials*

Carbon sequestration Kg C $ha^{-1}yr^{-1}$						
Practices	Mean	Lower 95% CI of mean	Upper 95% CI of mean	Min	Max	Number of estimates
Trees/forest	1204	798	1610	273	1732	125
Afforestation	1163	619	1706	97	5880	37
Woody perennials	1359	755	1964	147	9135	44

** The mean score of soil carbon sequestered in afforestation land management practices was used for computation*

The carbon sequestered was calculated in terms of tCO_2eha^{-1} yr^{-1}, which can expressed as a climate change mitigation benefit. Table 2 presents the different values for each of Trees/forest, Afforestation and Woody perennials based on the mean amount of carbon sequestered. Woody perennials have the highest Climate Change mitigation potential with 4.99 and 7.53 tCO_2eha^{-1} yr^{-1} respectively. This is followed by the trees/forest 6.69 tCO_2eha^{-1} yr^{-1}. These practices will among other considerations for other factors be interpreted cautiously as effective for climate change mitigation.

Table 2: Climate Change mitigation benefits of trees/forest, afforestation and woody perennials

Practices	Mitigation potential $tCO_2eha^{-1}yr^{-1}$	Land Emissions[a] N_20 and CH_4 t $C0_2e$ ha^{-1} yr^{-1}	Process Emissions[a] t $C0_2e$ ha^{-1} yr^{-1}	Net Impact t $C0_2e$ ha^{-1} yr^{-1}
Trees/forest	4.42	0.76	1.51	6.69
Afforestation	4.27	1.41	1.87	7.55
Woody perennials	4.99	0.76	1.78	7.53
[a] All values in this column are from (Eagle et al., 2010)				

Conclusion

This review has revealed that there is high potential to sequester additional carbon through trees/forest, afforestation and woody perennials. Most of the review covers carbon sequestration and modeled values or estimates as published. Estimates of soil carbon sequestration rates were converted to net climate mitigation benefits (abatement rates) by converting the C sequestration rates to carbon dioxide equivalent and adjusting for emissions associated with the land management technologies (Eagle, et al 2010). The analysis considered the fact that most studies reported soil carbon in different units. In some cases, only a single value, either initial or average across treatments, was provided for bulk density. In these cases, that value was assumed to apply to all treatments. If no bulk density information was provided in a paper (or other reports about the same study cited by that paper), then bulk density was estimated using known pedotransfer functions (that is, simple regression equations) developed for that region or extracted from the International Soil Reference Information Center–derived soil properties database. The most prominent practice is woody perennials (cocoa, oil palm and rubber plantations). The performance of these practices depends on soil properties and climatic conditions, and the degree of soil degradation at the time of intervention. African countries are unlikely to engage in soil carbon sequestration unless there are clear local economic and societal benefits. Therefore, it is essential to estimate all potential costs and benefits related to the various management options. Large-scale adoptions of ecologically sound land use practices are likely to be the most cost effective and environmentally friendly option to increase soil carbon sequestration in Africa (Tieszen 2000). There is need for more awareness of the use of trees, forest, afforestation and other woody perennials for climate change mitigation other than the prevalent socio-economic uses.

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Sustaining soil natural capital through climate-smart farmland management

Ernest L. Molua[1], Marian S. delos Angeles[2] and Jonas Mbwangue[3]

Summary

Sustainable soil management is essential for food security and agricultural sector growth. Increased degradation and declining fertility in the advent of increasing climate variability and climate change is impacting negatively on farm performance in sub-Saharan Africa. This paper reviews the economics of soil management in the World Bank's Sustainable Natural Capital programme pilot sites in Cameroon and unveils perspectives in developing soil fertility solutions through sustainable land management programmes. While noting that healthy soil is fundamental for sustained agricultural productivity, a comprehensive framework is proposed for sustainably managing soil natural capital under an exogenous driver of climate change. This will facilitate rolling-out farmland soil techniques that are climate-smart, and simultaneously enhance productivity increases and soil ecosystem resilience.

1. Introduction

Most countries in Sub-Saharan Africa (SSA) largely depend upon their natural resources for their basic livelihoods and economic development. Healthy soil is wealth for agro ecosystems, being important in crop production through supporting the fundamental physical, chemical, and biological processes that must take place in order for plants to grow; as well as regulating water flow between infiltration, root-zone storage, deep percolation, and runoff (Dominati et al 2010; Barrios, 2007). However, two major factors, namely (i) land-use change associated with population dynamics, and (ii) global climate change, threaten the longer term sustainability of the soil natural resource base. Soil is a natural capital essential for food security, agriculture sector growth and sustainable land management (FAO, 2001). However, the increased degradation and declining fertility of SSA soils contribute to food insecurity and poverty (Dale, 2007; FAO, 2001). The World Bank, FAO and partner agencies have supported the implementation of national Soil Fertility Initiative action programmes to tackle the problem. Furthering this effort, in 2007 the World Bank initiated the Sustaining Natural Capital (SNC) capacity building program, under the auspices of the World Bank Institute[4]. Cameroon was amongst one of ten target countries in SSA, which also included Burkina Faso, Burundi, Chad, Ghana, Guinea Bissau, Kenya, Liberia, Nigeria and Senegal.

The efforts to improve soil fertility management are challenged by increasing climate variability and climate change which are already having an impact on agriculture and food security as a result of increased prevalence of extreme events and increased unpredictability of weather patterns (FAO, 2009; Lobell et al 2008). The impact of climate change on agriculture and agriculture's contribution to greenhouse gases present an opportunity for renewed Climate-Smart Agriculture (CSA) practices that simultaneously promote adaptation and mitigation. CSA, as defined and presented by FAO at the Hague Conference on Agriculture, Food Security and Climate Change in 2010, contributes to the achievement of sustainable development goals. However, missing from recent studies in CSA and SNC with respect to soil fertility management is adequate recognition of the role of economics in soil productivity at farm, national and global levels (Turner and Daily, 2008; Ekins et al 2003). This paper attempts to address this shortfall by reviewing the returns to soil fertility management as precursor for CSA.

2. Materials and methods

Data is drawn from research survey with participants in the World Bank's SNC pilot sites, in the West and Northern regions of Cameroon. Two hundred and fifteen farms were studied in six communities within these three regions: North region (Fada, Gamba and Mayo Lebri), Adamawa region (Njoundé) and West region (Lagui and Kouptamo). These regions experience different variations of climatic regimes, particularly the effect of differing topography on their microclimates. The sahelian North region where rainfall averages 500–1000 mm per year is drier than the Adamawa region (900 to 1,500 mm per year) and the West region (1,000 to 2,000 mm per year) Specific assessments were undertaken to identify suitable agricultural production technologies and practices which address the complex interrelated challenges of food security, development and climate change, and identify integrated options that create synergies and benefits as well as identify barriers to adoption, especially among farmers, and recommend a framework for policies, strategies, actions and incentives.

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[4]For more information about the SNC program, visit: http://www.worldbank.org/wbi/environment/snc

3. Results and discussion

Most of the small-scale producers studied were already coping with degraded nutrient poor soils. They report having limited assets and risk-taking capacity to access and use modern technologies and financial services. Adoption of soil management options to manage moisture-related stress were reported by 16.7%, 31.7% and 12.3% of farm households in the North, Adamawa and West regions, respectively,. Other measures include various indigenous crop management measures and socio-cultural practices, such as planting in mixed and/or intercropping systems, as part of a scheme of crop rotation or in agroforestry systems. Soil nitrogen and other nutrients are recognized as essential to increase yields. Farmers rely on composting manure and crop residues, or using legumes for natural nitrogen fixation. There are, however, conspicuous differences between the choices in drier northern Cameroon relative to the humid western part of the country. The agroecologically less favoured communities in the sahelian North region use a variety of risk minimization strategies based more on biological sources of nutrients, resilient crop varieties or species, and integrated land and water management. In the North region, methods and practices that increase organic nutrient inputs (e.g. compost and manure) are fundamental and compliment farmers' investment in synthetic fertilizers which, due to cost and access, are rarely available to them. Farmers in the West region put more emphasis on inorganic soil fertility management with the possibility of shifting to new farmland sites as soil fertility declines. In some farm plots in the Adamawa region, nutrient stocks and flows of soil fertility are managed through a range of other strategies that promote nutrient recapitalization by combining organic and inorganic nutrient sources, e.g. applying inorganic fertilizers, using organic manures and legumes to fix atmospheric nitrogen. This is reinforced, in the humid West region, with production practices that emphasize soil productivity through integrated nutrient and water management, e.g. no-till production, conservation tillage, or mixed cropping that combines food crops with cover crop legumes and/or tree and shrub species. Specifically, managing soil physical and biochemical properties include a range of farm-level private autonomous measures such as stone terracing, soil bunds and construction of live fences. In all the three regions, traditional slash and burn farmland preparation by low-income farmers and the application of organic and inorganic fertilizers are significant activities in their soil management repertoire.

The farmers were found to have considerable knowledge of the rainfed ecosystems they operate, making informed decisions based on experience regarding the choice of cropping patterns and various management options. However, the cultivars grown are often not adapted to the climatic conditions since they are not indigenous but cultivars developed for the enhancement of other traits rather than their climatic relevance. Hence, while there is considerable traditional knowledge of rainfall and temperature variability, farmers are still sceptical about the short- and medium-term benefits of the new crops/cultivars that are introduced. More than 60% perceive changes in local climate. To cope with climate change, specific management practices are taken into account: the types of crop, grazing and forest systems, the diversity and current status of soils (e.g. sand/loam/clay soils, peat soils, sodic soils, shallow soils, nutrient depleted soils, etc), terrain (e.g. steep/flat lands, wetlands) and climatic conditions (e.g. short rainy seasons, erratic rains, high temperatures, storms). Farmers expressed a need for a climate information portfolio to enhance their productivity with the following information: date of onset of rainy season, quality of rainy season (rainfall amount), date of end of rainy season, frequency and timing of adverse weather events e.g. floods/dry spells within the season, temporal and spatial distribution of rainfall, interpretation of weather forecasts in terms of which crops and varieties to plant and when to plant. Hansen et al (2008) reiterate the feasibility of such climate forecasts improving farm outputs.

Farmers were then grouped and evaluated on their average ex-post economic returns to climate-smart soil management practices. In the North region, the average farm income for SNC practicing farmers is estimated at 215,000 FCFA (US$ 430) per hectare, in the Adamawa region it averaged 167,000 FCFA per (US$ 334) hectare and 124,000 FCFA (US$248) per hectare in the West region. The return-on-investment (ROI) computed as percentage ratio of farm profit to soil enhancement costs was 137%, 122% and 115% for farmers in North, Adamawa and West regions, respectively. This indicated that the farmers were likely to realise 37%, 22% and 15% above the capital invested in soil management. The internal rate of return (IRR) which captures the marginal efficiency of investment for such farmland investments were 17% minimum and 28% maximum for the North region, 14% minimum and 23% maximum for the Adamawa region and 11% minimum and 19% maximum for the West region. The Benefit Cost Ratios (BCRs) at 10% discount rate were 3.8, 2.5 and 1.6 for farmers in the North, Adamawa and West regions, respectively. Consistently, private farmland investments with respect to SNC recommended organic soil productivity improvements observe higher returns in the drier regions of the country relative to regions with increasing investments in inorganic soil enhancements. Though location specificity may be driving these differences, the general conclusion may be that of overall attractiveness of adopting low cost improved soil management measures in climatic risky locations. However, rolling-out such effort will require proactive and effective government support at the production and distribution stages of agricultural production.

In a forum for the Cameroon Parliamentarians' sub-group on environment to raise awareness on issues related to SNC and Climate Change Adaptation, it was unanimous that farmers' capacity to make the required adjustments depends on the existence of policies and investments to support their access to credit, insurance, as well as on proper economic incentives. Policy is important to shape the incentives and enabling environment to expand the opportunities available to such farmers. For example, inputs of information and technical expertise can facilitate changes in farm practices which improve the management of soil resources. The law-makers were unanimous tat the profitability of farm enterprises could motivate farm decisions, sustainable natural resource management and generate feedback effects on the natural and human resource attributes. If the sustainable resource management practices are not profitable the impacts may be to reject them, leading to degradation of natural capital, expressed as declining soil quality (Dale, 2007). On the other hand, if they are profitable, it will give positive feedback about sustainable natural resource management that reinforces households' resource base and improve on their perception of the plausibility of regarding them as acceptable farm practices. Policies that create enabling incentives are therefore primordial in shaping farmers' decisions. However, the survey reveals that the adoption of CSA options is also constrained by a lack of tenure security, which may affect farmers' incentives to adopt because of the time delay in enjoying the benefits from CSA and farmers' limited access to finance and insurance.

Figure1 below highlights a comprehensive framework for sustainably managing soil natural capital under the exogenous driver of climate change. The framework consists of five main interconnected components: (a) soil natural capital, characterised by standard soil properties; (b) exogenous drivers of soil change; (c) direct and indirect benefits from soil e.g. provisioning, regulating and cultural ecosystem services; (d) private farmland management choices and (e) policy linkages to enhance soil ecosystem services. It is a holistic approach linking soil ecosystem services (Daily et al 1997) to soil natural capital (Costanza and Daly, 1992). Through policy linkages, the promotion of research, technology development and extension, farmers could be provided with more tools to manage soil properly and enhance its ecosystem services - beneficial flows arising from natural capital stocks (Porter et al 2009; Swinton et al 2007). Policy-makers may borrow from a set of tools or instruments, such as rural credit programmes, input and output pricing policies, including input subsidies, property rights, extension services as well as the implementation of safety net programmes, they can apply to change the incentives and enhance capacity of farmers in their private investments on sustainable soil management. The policy environment would have to provide for market access (for inputs and outputs), competitive input costs and attractive producer prices to incentivise adaptation and adoption of soil productivity management measures.

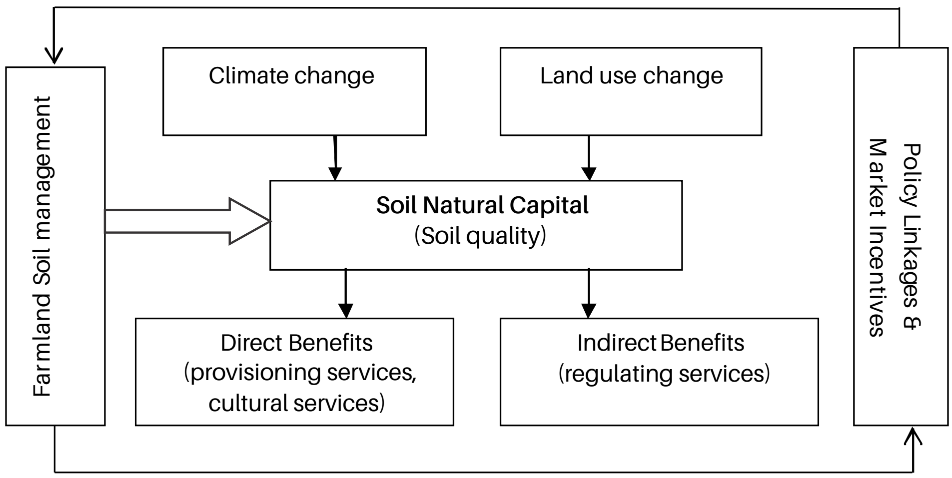

Figure 1: Framework for sustainable management of soil natural capital
Source: authors' conceptualisation

4.Recommendations and conclusion

Enhancing agricultural performance requires agricultural production systems to be productive in the face of climate risk. The World Bank SNC program highlights evidence of the benefits of sustainable land management choices that are climate-smart, in terms of productivity increases and resilience. To achieve agricultural development goals, adaptation to climate risk must be accomplished without depletion of the natural resource base, especially the soil resource. Management practices that increase soil organic carbon content from year to year through organic matter management will bring win-win benefits. In the pilot survey in Cameroon, good soil productive management was shown to contribute to farm income for climate change perceiving farmers. However, there is still need for in-depth study of the market, policy and institutional factors that would shape and structure farmer incentives and investment decisions in rolling-out SNC approaches in CSA enterprises.

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Agricultural intensification by small-scale farmers in hydromorphic wetlands as a tool to counteract climate change effects: a case study in Xai-Xai district in Mozambique

Paulo Chaguala[1] and Laurinda Nobela[2]

Summary

Climate Change phenomena is a threat for rural communities living basically with agriculture particularly smallholder farmers lacking financial means and knowledge on good soil management practices of lowlands. The availability of water in lowlands and easy way of irrigation through capillary ascension with a well defined dry period make it possible to have two or more growing seasons a year, rice crop in rain season and other crops in dry season. The study was carried out in Xai-Xai district located in southern part of Gaza province, Mozambique in a semi-arid area threatened by changing in climate, is crossed by Limpopo river, the major soil types are arenosoils in the upper land and hydromorphic soil in low land. Smallholder farmers in the surrounding communities were used to grow their crops in the upper lands avoiding low lands before experiencing continuous crop failure as a result of climate change due to the type of predominant native vegetation associated with poor soil drainage what make land preparation difficult. The lack of knowledge on management of hydromorphic soils by the smallholder farmers was another reason of not exploring this land. The study objective was to understand how crop production should be intensified under this ecosystem and promote better soil, water and crop management practices. Crops like rice, in rain season and maize, onion, common beans and cabbage in dry season were cultivated. By doing so, farmers were able to produce self sufficient food and raising family income all over the year, meanwhile their skills on use and management of these type of soils were improved. Crop yield of maize in the lowland is more than three times high (1500 to 3000 kg/ha) compared to upper land (200 to 800kg/ha). The intensification reduced food insecurity in the community and creates a source of income. Farmer's ability to use soil resources in hydromorphic in a sustainable way was improved.

Introduction

Xai Xai district in Mozambique has a large area of hydromorphic soils in seasonally flooded wetlands locally known as machongos, with medium to high potential for crop production (rice, beans, maize, potatoes and vegetables) along the Limpopo river. Such wetlands cover large areas also in other parts of Africa, where they are known as vleis (South Africa and Zimbabwe), dambos (Zambia), Mbugas (East Africa) and fadamas (West Africa) (Daka, 2001). The annual average rainfall in Xai Xai district is 1135.9 mm and with an average temperature of 22.3°C (Kassan and Velthuizen, 1981). The nature of the soil types and predominant native vegetation associated with poor soil drainage make land preparation difficult. Thus most farmers were cultivating only small areas to grow sweet potatoes and vegetables for home consumption during the dry (non-flood) season. However, the constant crop failure experienced in the uplands due to climatic variations changed the farmers' attitude. They started to invest more effort in the use of the low lands. They asked for help from extension services and researchers regarding improved utilization and management of these soils. It was in this context that demonstration experiments with rice, maize and cabbage were conducted at the Poiombo Farmers Association community in Xai-Xai district (24° 55' 47.5" S; 33° 42' 33.3" E). The main objective of the experiments was to demonstrate integrated soil fertility management (ISFM) practices in managing and cropping in seasonally flooded hydromophic soils. A specific objective was to develop a nitrogen fertilization and management package for rice production in that specific type of environment.

Material and methods

Site description

The land was permanently wet and agricultural use in these soils was impossible before a drainage system was installed After the establishment of drainage channels it was possible to regulate water depth. Hence limitations due to salinity, sodicity or acidity were minimized, making thess soils workable for agricultural practice all year round. The soil is a typical peat soil, formed by accumulation of organic materials, with a water table fluctuating between the surface and 40 cm as controlled by channel systems. Crop irrigation is basically through capillary rise of water from a water table.

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[3]Centimol (cmol) (+)/kg. Centimol (cmol) is a standard unit for expressing the concentration of cations in a comparable way

Table 1. Properties of the soil at the experimental site

									Extractable bases (cmol +/kg^3) (Ammonium acetate)			
Soil depth (cm)	**pH** H2O	**pH** KCl	**EC** 1:2.5 mS/cm	**H** cmol+ /kg	**Al** cmol+ /kg	**Total N %** (Kjeldhal)	**Avail P** mg/kg (Brayl)	**OM %** (loss ignition)	**Ca**	**M g**	**K**	**Na**
0-20	4.3	3.7	2.16	0.9	1.15	0.84	25.1	29.6	2.19	4.94	0.72	1.76
20-40	5.2	4.1	0.75	1.2	0	0.03	31.1	26.6	2.41	4.34	0.84	1.62

The soil is strongly acidic, with pH (Water) ranging from 4,3 to 5,2 (Table 1). The electrical conductivity (EC) varied from 0,75 to 2,16 mS/cm and thus only sensitive crops would be affected negatively by salinity, Total nitrogen is high in the top soil, but low in the subsoil. The soil's phosphorus content is optimal, varying from 25,1 to 31,1 mg/kg (Bray 1). Soil organic matter was very high (more than 25%) as is normal when dealing with peaty soils. The Ca/Mg ratios are very low (0.44 and 0.55) not favorable for calcium nutrition. At these ratios Mg will also cause dispersion of soil colloids, thus destabilising soil structure. The Mg/K ratios are high (6,86 and 5.17) as are the (Ca+Mg)/K ratios (9.90 and 8.04). These are, however, still acceptable for potassium absorption.

Methodology

For the rice experiment the experimental design was a split plot with three levels of nitrogen (0, 80 and 100 kg ha^{-1}) as main plot and four rice cultivars (Makassane, M'ziva, IR 64 and Limpopo) as sub-plot, using three replicates. The 80 kg N/ha application rate was calculated based on soil analyses and crop requirement (Frank Bernard method). The 100 kg N/ha application rate was extracted from the general fertilizer recommendation of annual crops of Mozambique (Comunicação N^o 88, INIA). To ensure phosphorus won't be a limiting factor for nitrogen absorption and to ensure soil P maintenance 6.2 kg/ha P were applied in all treatments except in the control simulating farmers' practice. According to research results the potential productivity of the selected cultivars are 7-7.8 t/ha for Makassane, 3.5-4 t/ha for M'ziva and 5-6 t/ha for both Limpopo and IR64. All four selected cultivars are long season cultivars, with growing periods ranging from 120 days for IR64 and Limpopo to 128 days for M'ziva and 130 days for Makassane.

Due to the grassland nature of natural vegetation predominant in this type of ecosystem for land clearing a non-selective herbicide was sprayed instead of the traditional way of burning. It was to demonstrate to the community that burning is not a good practice to clear an organic soil, since it can cause drastic harm to the soil and environment. The experiment was planted during the last week of November 2013, after starting of the rain season. The planting density was 166 667 plants/ha.

Experiment on conservation agriculture: soil nutrient use efficiency for maize intercropped with leguminous crops, under till and no-till systems

The first objective was to demonstrate the advantage of the use of total herbicide (glyphosate, commonly called roundup) in land preparation compared with conventional tillage; and evaluate the contribution of a conservation agriculture system to soil nutrient availability and crop yield. The second objective was crop diversification with maize as a staple food and beans as diet improvement and for income generation.

The trial was planted in the cool and dry season of 2013 and the experimental layout was a split plot design with land preparation (tilled and no tilled) as main plot and fertilizer application as sub-plot (3 levels of nitrogen 0, 40 and 80 kg N/ha) with a basic phosphorus application of 18 kg P /ha; with three replications. Matuba variety was used for maize and PAN 148 for phaseolus vulgaris; maize was planted at spacing of 80cm x 40cm and the beans were planted intra maize rows. The fertilizer application was localized per hole where N fertilizer was only applied for maize while P fertilizer was for both crops. The second phase of the experiment was planted in the cool dry season of 2014. The highest level of N fertilizer (80 kg/ha) was omitted as no significant difference was observed between it and the lower level of N (40kg/ha) during the first season.

Effects of mineral fertilizers on cabbage yield in the Machongos

The objective was to evaluate the effect of minimum application rates of nitrogen on cabbage yields in this type of soil. An on- farm experiment was established the during cool dry season after the rains in a split plot design with 2 levels of land preparation (till and no-till) as main plot and fertilizer application as sub-plot with 4 levels of nitrogen (0, 20, 40 and 80kg N/ha) with 3 replicates. The variety Gloria F1 was cabbage. The experiment was planted at the spacing of 60cm x 40 cm and the fertilizer application was localized by row. Obtained yield results were statistically analyzed using Statistx 9 package.

Results and discussion

Rice experiment

Where no fertilizer was applied the average yield of all cultivars ranged between 1.8 to 2.2 ton/ha and there were no statistically significant differences (Figure 1). The cultivars reacted significantly different to application of different levels of nitrogen. IR64 and Limpopo showed very high yield increases in response to N application. Their responses were of the same order and not statistically different. Both these cultivars reached their genetically potential yields of 5-6 t/ha at the two highest N application rates. Makassane and Mziva showed relatively poor responses compared the other two cultivars to N fertilization, giving statistically significantly poorer response. At the highest N application rate the yield of Mziva did nearly double and it reached its genetic potential of 3.5 to 4 t/ha. Makassane was the big disappointment, reaching a yield of less than 3 t/ha, while having a genetic potential of 7-7.8 t/ha. It is possibly not adapted to strongly acid soil conditions, such as prevailed at the experimental site. It shows the importance of selecting adapted cultivars for specific conditions. The application rate of 80 kg/ha administrated based on Frank Bernard calculations revealed to be agronomically efficient since the increase to 100kg N/hayield increase was low and not statistically significant.

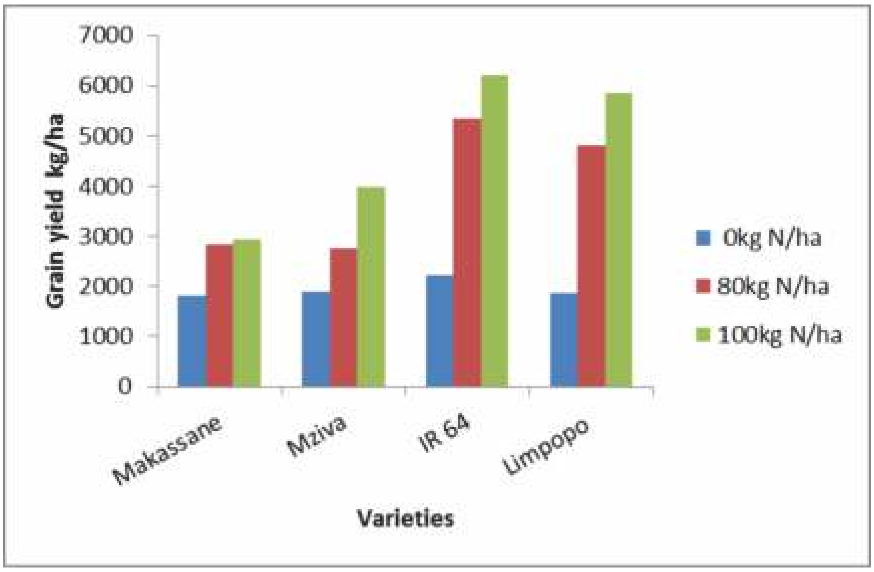

Figure 1. Average rice grain yields

Results for the conservation agriculture experiment with maize

For all treatment combinations maize yield was superior under the no-till system in the first year of the trial (2013), but the yields were extremely low (Figure 2). The beneficial effect of no-till could be explained by the rapid evaporation on tilled plots associated to low level of water in the channels and it took too long to raise the soil moisture by capillarity. Under no-till yield was approximately doubled compared to control (means maize sole crop without fertilizer) for all fertilized plots while in the intercrop without fertilizer the yield increase was 205 kg/ha (about 50%). thus, intercropping maize with beans had a positive effect. In the tilled plots fertilizers had very little effect, while intercropping with beans had a small negative effect. The latter was probably due to the higher water demand by the larger number of plants (maize + beans) in these water stressed plots.

In the second season of the trial (2014) the trends changed drastically (Figure 3).Maize yields were still low, but much higher than during the previous season. Under no-till N fertilizer alone and beans without fertilizer gave about equal yield increases, with the combination of beans and fertilizer being slightly inferior to these. Under till the N fertilizer alone performed poorly. The big difference compared with the previous season was that the tilled plots with beans alone outyielded the no-till plots and especially that the tilled plots having both beans and N fertilizer far outyielded all other treatments. The main reason for the differences between the seasons was that, unlike in the previous rainy season the rains were good during this season and thus the channels maintained high water levels. the average maize yield for the control treatment (no fertilizer application or beans) was 823 and 971 kg/ha for no-till and tilled respectively, and for intercropped plus fertilized plots 1122 and 1686 kg/ha for no-till and till systems respectively.

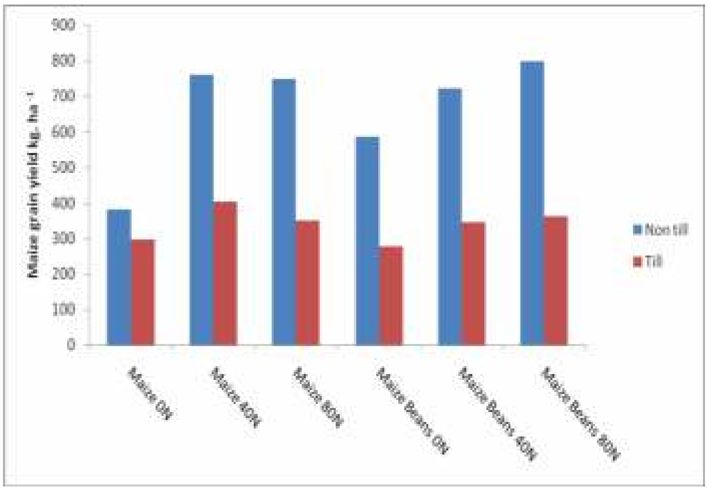

Figure 2. *Maize grain yield 2013*

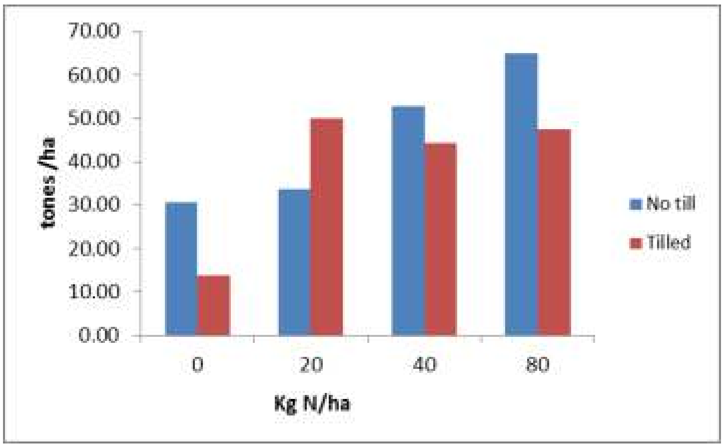

Figure3. *Maize grain yield 2014)*

Results for the conservation agriculture and nitrogen experiment with cabbage

Figure 4 represents cabbage response to N-fertilizer under till and no-till systems. In the tilled plots yields increased sharply above the control at the lowest N application rate (20 kg N/ha) and then levelled off. In the no-till plots the yield was significantly lower than in the tilled plots at the lowest N level, but then rose sharply with each further increase in N application. Consequently at 40 kg N/ha there was no difference between the tilled and no-till plots, while at an application of 80 kg N/ha the yields in the no-till plots were significantly higher than in the tilled plots. So, for poor small-scale farmers a combination of till and low N application (20 kg N/ha) would by far be the most feasible combination.

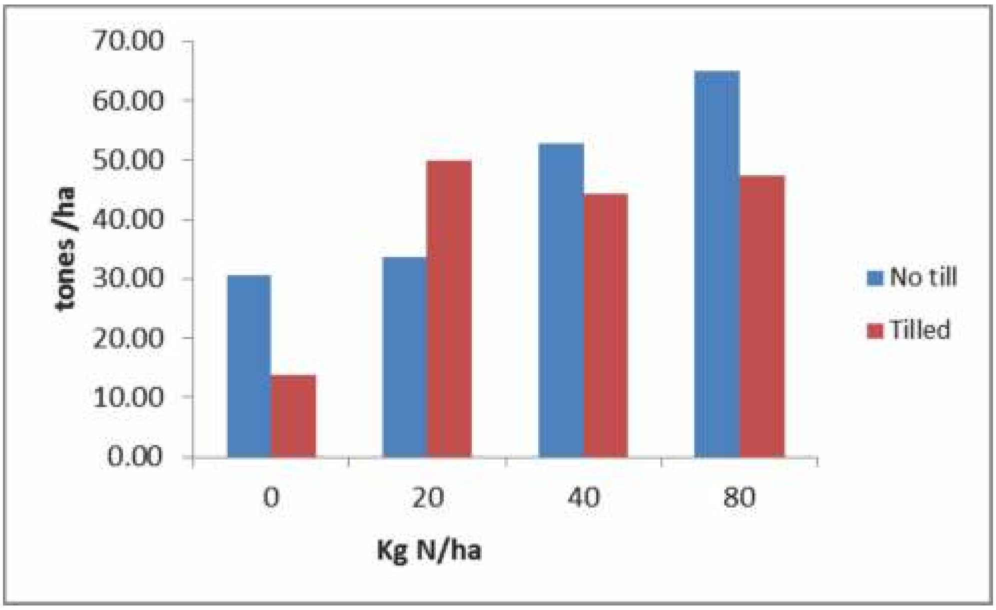

Figure4: Cabbage response to N-fertilizer

Conclusion and recommendations

Agricultural intensification in hydromorfic soils can help in building or strengthening rural communities' ability and skills to overcome climate variability and climate change threats by providing food all year round and improving family diet, as well as creating a source of income through cultivation of vegetable crops. It is highly recommended to grow maize and vegetables during the dry season after growing rice during the rainy season.

Using leguminous crops intercropped with maize and the use of minimum application rates of N results in a positive and relatively cheap contribution to crop production for small-scale farmers. Increased crop production will require a reliable market to sell the surplus. This calls the attention for the need to develop community storage and agro-processing methods.

For reliable conclusions and development of appropriate production packages an economic analyses is recommended.

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Soil fertility and climate benefits of conservation agriculture adoption in the highlands of Tanzania

Janie Rioux[1] and Marta Gomez San Juan[2]

Summary

The restoration and maintenance of soil fertility is essential for agricultural productivity and food security in rainfed low input agriculture. Conservation Agriculture (CA) is one set of practices that can reduce soil erosion and restore soil fertility, thus improving yield, and contributing to climate change adaptation and mitigation. This paper presents the effects of CA on maize yield and greenhouse gas (GHG) fluxes in the highlands of Tanzania. The results showed that some CA practices (reduced tillage plus mulch and soil nitrogen remediation with leguminous trees or N fertilizer) have the potential to substantially increase maize yields without increasing GHG emissions, giving more favourable ratios yield: GHG emission. A high number of farmers reported the adoption of individual CA practices, ranging from 83% for minimum tillage to 86% for mulching. However, when looking at the management of their three main plots, the rate of adoption of the promoted CA package (reduced tillage plus mulch and intercropping) was low: 45% for one practice and only 6% for practicing two CA sub-practices at a time, and no one practiced the full package of three CA practices. This shows that whereas scientists set complete packages, farmers choose and try the individual components of a package. The main factors determining adoption were wealth and food security status, land tenure, land availability, labour, perceived payoffs and access to information and training. The paper concludes that increasing yield can be achieved in synergy with reducing GHG emissions, but that the barriers to adoption need to be addressed. Moreover, incentive mechanisms should also be put in place to promote the adoption and up-scaling of sustainable soil management practices like conservation agriculture.

Introduction

Conservation agriculture (CA) practices are widely promoted as part of sustainable soil management and climate-smart agriculture in Sub-Saharan Africa. The benefits of these practices on yield are caused by improved soil structure as well as increased soil fertility, carbon content, and water retention (Baker et al., 2007; Palm et al., 2014; Powlson et al., 2014). However, the effects of CA on greenhouse gas (GHG) emissions are uncertain in most African farming systems. Moreover, the barriers to the implementation of CA practices are complex due to their site-specific characteristics.

Therefore, the objective of the study was to test the impacts of conservation agriculture on yield and GHG emissions, and analyse the adoption rate and barriers of different CA practices.

Methods

From 2011 to 2014, the FAO Mitigation of Climate Change in Agriculture (MICCA) Programme implemented climate-smart agriculture (CSA) in two pilot projects in Kenya and Tanzania. The MICCA Pilot Projects promoted the development of a selection of CSA practices for smallholder farmers based on expert and participatory assessments. In the Uluguru Mountains of Tanzania, the menu included conservation agriculture (CA) practices, agroforestry, soil and water conservation, and energy-saving cooking stoves to improve yield and livelihoods as well as to reduce erosion, burning, and deforestation. Alongside implementation, the selected practices were evaluated in terms of their food production, adaptation and mitigation benefits. Moreover the adoption determinants were analysed to inform CSA up-scaling and future extension programmes.

The total area under analysis was 16 812 ha and included 18 326 people. The annual temperature ranges between 22 and 33 °C and the rainfall between 1 500 and 1 800 mm yr^{-1}, with the long rain period from March to June and the short rains from late October to early December. The data were gathered over twenty-one months, from October 2012 to June 2014, along four growing seasons and two fallow seasons.

Firstly, a study was conducted to assess the maize yield and GHG emissions from different sub-practices of CA in a 630 m^2 experimental plot in the village of Kolero. The experiment consisted of the rainfed cultivation of fifteen plots: three replicates of five different treatments, two that were practiced in the area (1 and 2) and three that were promoted by MICCA extension activities (3, 4 and 5): 1) conventional cultivation with hand hoe tillage and random planting; 2) reduced tillage plus mulch in-between rows; 3) reduced tillage plus mulch and Lablab leguminous cover crop; 4) reduced tillage plus mulch intercropped with leguminous *Gliricidia sepium* trees; and 5) reduced tillage plus mulch and mineral fertilizer (75 kg of N/ha). Reduced tillage plots were prepared by first double digging the soil before the rainy season of 2012, as a first step in order to prepare the land for the further adoption of reduced tillage. They were stick planted with maize Tan250 and the cover crop was sown ten days prior to the planting of the maize. Also, *G. sepium* trees were planted seven months earlier and their foliage biomass was added to the soil after pruning (2 to 3 times per growing season).

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[3]*www.fao.org/climatechange/micca/pilots/en/*

- Maize yield was determined by the estimation of dry weight per plot, based on the ratio of dry-to-fresh weights (dried in an oven at 70°C). Both, the final maize grain and stover yields were expressed in Mg ha^{-1}. For the *G. sepium* intercropping, the N input from the green manure of foliage biomass left on the soil was measured at each pruning time. The test consisted of oven drying and nutrient analysis, and the total N was calculated as a function of dry matter mass and N concentration.

- GHG flux measurements were carried out with static chamber techniques. Chambers were 27 x 37.2 x 10 cm and were placed one week prior to the first measurement and kept in-situ over the whole season. Each sampling plot had two chambers, one within a row between two plants of maize and one between two rows. During the samplings, the chambers were sealed for 30 minutes and every 10 minutes the gas on the headspace was removed using a 60 mL syringe. ICRAF analysed the sample content with gas chromatography and converted them on a mass per volume basis. The SAS system was used to analyse the normality of the yield and GHG data, at a 5% level of significance.

Secondly, structured household interviews (sample size n=169 with 51% women) were conducted alongside focus group discussions (n=5) of 6-10 participants each. This was needed to gather quantitative and qualitative information on the determinants and outcomes of CSA adoption in 8 villages in the Uluguru Mountains where the MICCA pilot project was implemented. A proportionate random sampling was used to select respondents from the different villages, among the project participants.

The random sample of the project participants was computed as the ratio of the number of farmers who received trainings to those who participated in initial awareness raising with a 95% confidence level and 7% confidence interval. The sample was proportionate among locations, as the main strata for sampling, and ultimately balanced by gender. Data was analyzed with the Statistical Package for Social Scientists (SPSS 20) software.

Households were the unit of sampling for the questionnaires. Data were collected on household and farm characteristics, participation in MICCA project activities, CSA practices (adoption rate, constraints and incentives), and benefits on food security and livelihoods. The sampling had already taken into consideration the participation in trainings and rated the number of farmers who received trainings to those who participated in initial awareness raising.

Results

Results from the field experiment

The yields, GHG emissions and GHG emissions per yield unit for different sub-practices of the CA package and conventional tillage are presented in Table 1.

Kimaro et al. (2015) reported that increases in maize yield were statistically significant with the treatments including *G. sepium*, and fertilizer. Significant differences ($p<0.05$) in maize yield were found between conventional cultivation and cultivation using the treatments of the *G. sepium* and fertilizer, for three of the four seasons analysed. No significant differences were found between *G.sepium* and fertilizer practices and between the ones including lab lab and mulching.

However, regarding the annual emissions, the differences were insignificant across treatments ($p>0.05$). When looking at the GHG emissions intensity (GHGi), i.e. GHG emissions per unit of yield in Mg CO_2eq Mg $maize^{-1}$, the *G. sepium* and fertilizer practices show more potential, in addition to the fact that they are the two practices that produce a greater yield increase of 54% and 43%, respectively.

Table 1. *Effects of different practices on annual maize yield and annual GHG emissions and GHG emissions intensity*

Parameters (yearly-basis)	Conventional tillage and random planting	Reduced tillage plus mulch	Reduced tillage plus mulch and Lablab	Reduced tillage plus mulch and G. sepium	Reduced tillage plus mulch and N fertilizer
Maize yield (Mg ha^{1})	3.7	4.5 (22%*)	4.6 (24%*)	5.7 (54%*)	5.3 (43%*)
Soil GHG emissions (Mg CO_2e ha^{-1})	4.6	5	5.1	5	4.7
GHGi (Mg CO_2e grain Mg^{-1})	1.2	1.1	1.1	0.8	0.8

(***Source:*** *Kimaro et al., 2015)*

* = Percentage increase above the yield with conventional tillage

Results of the farmer survey

The promoted package of CA included minimum tillage, mulching and cover crops/intercropping. A high number of farmers reported practising single conservation agriculture practices, as can be seen in the Figure 1 below. However, for their three main plots (i.e. bigger size and from which they obtain the majority of their production), the adoption rate was lower, and even more for combined conservation agriculture practices. Indeed, when looking at the management of their three main plots, the rate of adoption of the promoted CA package was low: 45% for one practice and only 6% for practicing two CA sub-practices at a time. No farmer practised the full package of 3 CA sub-practices.

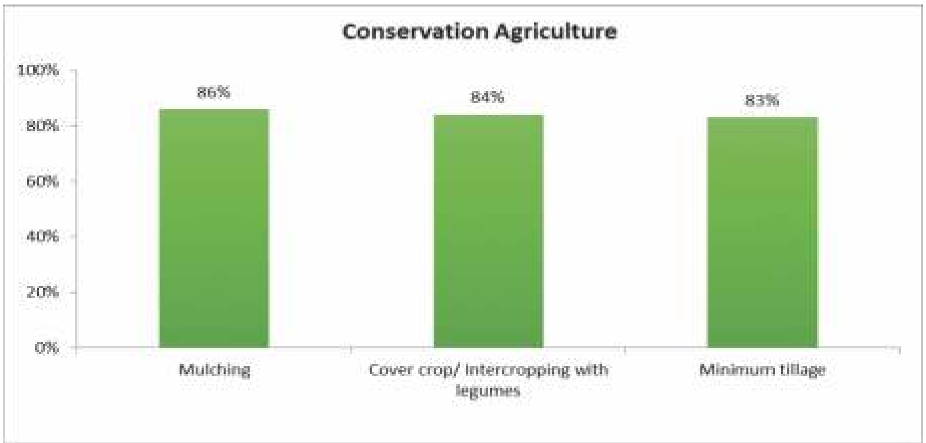

Figure 1: *Percentage of farmers practicing individual conservation agriculture sub-practices (FAO, unpublished data)*

Main adoption determinants reported by farmers surveyed in the study were wealth and food security status, land tenure, land availability, labour, perceived payoffs and access to information and training, many of them also mentioned during focus group discussions. For example, wealthier households were practicing crop rotation because they own more land, and mulching for growing vegetables, which requires inputs, tools and access to markets. On the other hand, farmers who rent land also adopt mulching, as this is a temporary, cheap and easy to try practice and it also helps to fight soil erosion on slopes. Insecure land tenure was mentioned as a barrier to the adoption of conservation agriculture.

Land availability was another commonly cited barrier, as farmers having limited access to land find it risky to test new practices. Labour (availability and/or cost) was also a constraint for testing and implementing new practices. The perception of high productivity payoffs in terms of increased yield is a key factor in the adoption of mulching and cover crop (Table 2). In FGDs, farmers see the potential for improving productivity, especially on the hillslopes. The absence of proper access to information was also a barrier in the adoption of CA practices. The establishment and promotion of Farmer Field Schools was a successful factor in adoption (Figure 2). Micro-credit groups can also help farmers, especially women and youth, to adopt new practices.

Table 2. *Barriers and incentives in the adoption of CA practices in the Kolero area*

	Barriers and Incentives
Mulching	Perceived as having the lowest productivity payoff of all CA practices, but as being one of the two most affordable practices. The main reasons for adoption and continued use given by around a third of farmers was the promotion by change agents, and the immediate benefits from adoption. Specific training increases adoption.
Cover crop/ intercrop-ping	Perceived as being one of the two most affordable CA practices. The main reason for adoption and continued use given by about 40% of interviewees is the promotion by change agents. Around a quarter of interviewees also recognized immediate benefits from the adoption of cover crops. Very few people disadopted cover crops.
Minimum tillage	Perceived as having the highest productivity payoff of all CA practices. Specific training and participation in Farmer Field Schools and demonstrations increase adoption Main reason for adoption is promotion by change agents. The main reasons for disadoption among the few that did so were their perception of low pay-offs and better alternative practices available.

Figure 2: Farmers practicing conservation agriculture (no tillage, mulching, cover crops/ intercropping)

Discussion and conclusions

The results from the MICCA Pilot Project showed that no conflicts exist between increased maize production and reduced GHG emissions through CA in this area of Tanzania. CA has several advantages for soils and crops that makes it a promising solution for sustainable soil management. However, the package of CA practices has multiple barriers to adoption. Farmers in Kolero tend not to adopt the full bundle of CA practices. The main benefit perceived by farmers is increased food availability, mainly through increased food production, which is relevant as 65 % households are food insecure in the area. However, it is important to note the implication of the results in Figure 1 and the finding that only 6% of farmers adopted two CA practices in their main plots, and that 0% are practicing three CA practices out of the complete CA package. It shows that despite scientists seeing practices as a package, farmers see and choose the individual components.

It is thus essential to better understand both the incentives and barriers to enhancing the adoption of the different components in CA. Adoption is highly influenced by training and farmer-to-farmer learning, hence farmer groups should be promoted and sustained, and reward mechanisms put in place for participants and trainers. Indeed, properly designed extension activities as well as technical support to motivate farmers towards the adoption of new practices and technologies are essential. Farmer groups, involvement of local level decision makers, and micro-credit schemes are necessary to implement and up-scale sustainable land management. It is important to link the promotion of specific sustainable soil management and climate-smart practices and technologies with sustainable extension services and incentives (e.g. income generating activities, stable markets, group learning, access to seeds of high-yielding or early-maturing crops, and access to loans). The scaling-up of promising sustainable soil management practices in different farming systems is key to inform the design of future extension programmes and investment plans.

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Observations from the field: impacts of conservation programming on community livelihood strategies and local governance structures in the eastern arc mountain range, Tanzania

Dana M. Baker[1]

Summary

This research investigates the impact of conservation programming on livelihood strategies and local governance structures across selected sites in Tanzania. The research presented is part of a larger global study, conducted in collaboration with researchers at Yale's School of Forestry and Environmental Studies, examining the factors that foster replication, mainstreaming, and up scaling of conservation and development projects across five countries.

Results in Tanzania show that conservation and development interventions have various degrees of success and impact. Within the scope of this study four key mechanisms that positively influence conservation programming and livelihood strategies will be discussed. These include: 1) the negotiation and establishment of local level policies, 2) the adoption of accountability and transparency mechanisms, 3) the shift away from collective forms of governance to allow stakeholders to profit on an individual basis, and 4) the promotion of market integration and utilization. Yet, even with a strong policy framework and international funding surrounding natural resource management and development programming there remain great challenges that impede the sustainable use of Tanzania's natural resources.

Introduction

Over the last decade, community based approaches to conservation and natural resource management have been widely criticized for failing to deliver tangible benefits for either the natural resource or the human community (Leach et al. 1999; Sheppard et al., 2010). This perception of failure has led many to question the validity of an integrated approach to conservation and development (Blaikie, 2006). Yet, the interdependence of biodiversity conservation and poverty alleviation mean neither can be effectively pursued in isolation. Today, both remain central to the policy agendas of developing states (Agrawal & Redford, 2006), despite the fact there is little evidence, or pragmatic experience, on the impact of conservation policies implemented around protected areas (PAs)(Castillo et al., 2006; Clements et al., 2014).

Currently, policy choices are limited by an absence of information regarding the impact of programming on local livelihoods (Agrawal & Redford, 2006). This research seeks to fill current gaps in literature by investigating the impact of community conservation interventions on livelihood strategies and local governance structures in Tanzania. Case studies offer the opportunity for comparison and analysis of the strengths of individual programs to successfully implement conservation and development interventions.

Materials and methods

The area of study, namely the Eastern Arc Mountain Range in Tanzania, encompasses some of the most important forest blocks in Africa (Burgess et al., 2000). It is widely recognised by international conservation organisations as a global centre for flora and fauna endemism (Global Environment Facility, 2006). In addition to increased protection efforts by the central government over the last two decades, a number of interventions have sought to involve local communities more directly in the management of forest resources (Ministry of Natural Resources, 2001). Many such interventions are focused directly on increasing the production of smallholder farms adjacent to PAs through soil fertility management, agro-forestry programming and small-scale irrigation schemes. Yet, other interventions focus on diversifying livelihood strategies to reduce the overall pressure on the region's natural resources.

A multi-sited approach was used to conduct a comparative analysis of the political, social, and environmental contexts of conservation programming in 14 selected sites across Tanzania located in three geographic areas of focus: Kilimanjaro National Park, the Eastern Arc Mountain Range, and Jozani National Park in Zanzibar. The scope of this paper is on the findings from projects evaluated in the Eastern Arc Mountain range, in which five of the sites were located. Study site selection was determined by several variables, including the focal area of the conservation intervention, time since project completion, and proximity to a nature reserve. The specific data and information collected at each site varied based on the goal of an individual intervention. However, indicators can be organized into four broad categories: 1. Changes in socio-economic status 2. Capacity development according to individual and institutional scales 3. Education and awareness on issues of natural resource management, and 4. Institutional and policy development.

Results and discussion

Conservation and development interventions across the Eastern Arc Mountains are strengthening the link between livelihoods, natural capital and poverty— a link that remains a fundamental challenge to Tanzania's forest conservation efforts. Four mechanisms were found to influence the outcome of conservation interventions: First, the negotiation and establishment of local level policies succeeded in defining and enforcing the sustainable management of natural resources within participating communities. Second, the adoption of accountability and transparency mechanisms enabled the design and the support of strong local

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institutions. Third, the shift away from a reliance on farmer groups allows farmers to produce and profit on an individual basis, increasing the motivation to enforce sustainable land management practices. And last, the promotion of market integration and utilization influenced positive conservation behavior by diversifying livelihood options for smallholder farmers.

The negotiation and establishment of local level policies helped secure water rights and land tenure across the mountain range (Table 1). For example, new village level by-laws in communities outside Chome Nature Reserve state that farmers receiving water from a newly built irrigation system must terrace their land and use agroforestry techniques. If a farmer does not agree to implement such practices, they will not receive irrigation water from the new system. Such a policy reinforces the sustainability of conservation programming by increasing the capacity of village governments to create and enforce sustainable behaviors. Three years after the implementation of this policy, participating farmers report a 200% increase in crop yield (Source: SAIPRO Agro Forestry Officer Monitoring Records, December 2012).

Table 1. Project name, implementing institution and summary of observed local level policy change with observed impact

	Project evaluated in the Eastern Arc Mountains: Name and Implementing Organization	Local Level Policy Change (Yes/No)	Observed Impact
1.	Improving livelihoods of Nilo Nature Reserve adjacent to local communities through implementation of non-consumptive activities. Implementing organization: *Nilo Nature Reserve*	Yes: Nilo Nature Reserve recently upgraded from forest reserve to nature reserve changing local access rights and policy.	Conservation programming built relationships with local community groups through farmer field schools, agro-forestry, and beekeeping projects. The elevated status of the reserve has restricted access to local communities increasing pressure and land degradation in outside communities, stressing relationships between stakeholders.
2.	Sustainable Conservation of Chome Nature Reserve through empowerment and active participation of adjacent communities. Implementing organization: *Tanzanian Forest Conservation Group*	Yes: Chome Nature Reserve was recently upgraded to nature reserve changing local access rights and policy. Project designed and implemented new land management plans and policies.	Project designed and implemented new land-use policies by formally mapping local resources. Plans strengthened the ability and capacity of village governments to stop encroachment and pumping of local springs and water sources. The elevated status of the reserve has restricted access to local communities increasing pressure and land degradation in outside communities, stressing relationships between stakeholders.
3.	Chome: Soil conservation and environment management on the highlands of Same District. Implementing organization: *SAIPRO*	Yes: only farms using soil conservation techniques will get water irrigated from new irrigation system. Farms must have terraces made by Dec. 2015.	200% increase in crop yield reported by participating farmers. Strengthening of village level authorities to enforce policy.
4.	Amani Butterfly Farming Project. Implementing Organization: *Tanzania Forest Conservation Group.*	No. Project focused on market integration and strengthening local level institutions to ensure transparency and accountability.	Project made 90,000 USD profit (2014). Community development fund used to build tap stands and expand electricity into participating villages. Community Development Fund and revenue sharing scheme fundamental to success, as is individual's ability to make profit.
5.	Support to community involvement in conserving biodiversity of Amani Nature Reserve, East Usambara Mountains. Implementing organization: *Amani Nature Reserve*	No policy change.	Won Equator prize (2008). Project focused on building demonstration plots and farmer field schools to showcase best practices, agro-forestry techniques, and beekeeping. Allowed reserve management to build relationships with community.

Engaging village governments to successfully create and apply local level policy, as seen in the villages surrounding Chome and Nilo Nature Reserves, highlights the importance of decentralization in rule setting for conservation program success. Other research supports the notion that the decentralization of authority is an important factor in improving program success, provided that strong local institutions are present (Agrawal & Redford, 2006; Garnett et. al., 2007). Ostrom and Hayes (2005) note the role of decentralized decision-making for the success of PA's in a global review of forest conditions inside and outside reserves. Their results show that forest conditions are related more closely to local involvement in setting rules on forest use than in any central system of park designation.

The importance of building strong local institutions for the successful implementation of conservation programing is evident in the communities surrounding Amani Nature Reserve. One enterprise development project, beginning in 2003, has grown from an initial training of 10 farmers to include over 150 individual farmers. The project provides subsistence smallholder farmers with a source of income that has minimal impact on the natural environment. Program activities have diversified livelihood strategies, decreasing reliance on farming as a sole livelihood activity. Two mechanisms contribute to the projects' success. First, a clear revenue sharing framework was established from the outset, whereby 28% of total sales are used for administration costs of the project, 7% goes into a Community Development Fund, and 65% is returned to individual farmers who are paid up-front according to each individual farmer's output. Individual farmers can see the direct financial impact from their effort—the more time and effort an individual puts into their enterprise, the more money they make at the end of each month. Second, the establishment of an elected committee that determines the groups' politics, finances, and marketing strengthens accountability, program transparency, and trust between stakeholders. The elected committee additionally controls all stages of the value-chain, from producers to buyers, reducing reliance on intermediaries, thus increasing profits for all involved.

Many conservation and development interventions continue to rely on farmer groups and collective governance models, where revenues generated are equally distributed throughout the group, despite some individuals not contributing and others putting in more time and effort. Despite advantages to this collective model– such as lower capital investment, as well as lower maintenance and labor costs, it is clear that farmers' individual productivity, and consequently the productivity of the entire community, is seriously impaired by such arrangements. Problematic group dynamics were solved in both cases discussed above through the creation of mandates allowing farmers to produce on an individual basis.

The role of market integration and utilization influencing conservation behavior is supported by the work of Stem et al. (2005). They found that when a viable enterprise is linked to biodiversity of a protected area and generates benefits for individuals within a community of stakeholders, stakeholders will act to counter the threats to the resource (Stem et al., 2005). However, known conservation benefits from enterprise development could also be result of a learning process that strengthens local institutions improving enforcement of the use of biodiversity, as well as the management of natural resources anda ecosystem services.

Conclusion

Projects evaluated here illustrate a diverse set of institutional arrangements between village level governments, national level stakeholders, and international organizations. The study reports that the successful implementation of biodiversity conservation and development interventions have to do with how communities are approached, the presence of strong local level institutions, and the development and implementation of mechanisms that ensure transparency and accountability of project funds. An interesting element that warrants further exploration is the move away from traditional approaches of collective governance and farmers groups to allow farmers to produce and profit on an individual basis. Yet, even with a strong policy framework and international funding surrounding natural resource management there are mounting challenges that impede the sustainable use of Tanzania's natural resources. This paper

Photo 1. Communities outside Chome Nature Reserve have experienced a 200% increase in crop yield after the construction of new irrigation channels and through the implementation of agroforestry and soil conservation techniques.
Photo credit: Dana Baker

Photo 2. A butterfly farmer stands next to his butterfly cage in a community outside Amani Nature Reserve. The project started in 2003 with 10 trained farmers and has now grown to over 150 participating individuals across 6 villages. Strong project leadership, transparency and accountability, and an established external market have significantly contributed to ongoing program success. Photo credit: Dana Baker

Photo 3. Small-holder farms bordering Chome Nature Reserve in Tanzania demarking a clear boundary between forest and agricultural lands. Photo credit: Dana Baker

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Analysis of sustainable livelihoods diversification of marine fishing communities in Benin

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Summary:

Marine fishing communities in Benin seek to diversify their basic income because fishing is no longer providing enough income to fully meet the household needs. Farmlands close to communities can serve as new sources of income. Therefore, market gardening has started gaining ground on sandy soils of the beach and on the ferruginous, slightly saline soils in the flood plains. To respond to the need for a sustainable management of soils and water, AfricaRice, International Fertilizer Development Center (IFDC) and the "Strategic Response to HIV/AIDS for fishing communities in Africa[4]" programme of the FAO are providing training and support for the youth in efficient and sustainable use of lands and water. The aim of this paper is to document how partners can use the dynamics of the youth in fishing communities as innovators for the introduction of efficient use of irrigation water combined with aquaculture and improved varieties to obtain a high income from rice farming and chilli production.

Two action-research protocols have been developed: one in collaboration with the Africa Rice Centre (AfricaRice), aimed at comparing rice varieties and the second in collaboration with the IFDC, aimed at comparing market gardening techniques and the combination of irrigation with the use of aquaculture tanks.

The results of rice variety tests have helped to identify high yielding rice varieties that can produce more than 5 tons/ha of lowland rice and 3 tons//ha of rain-fed rice. On the other hand, a comparison of irrigation systems for the production of NIKLY variety of chili has shown that production was higher with drip irrigation combined with the use of fish production tanks. The yield of this double production reached 10.691 kg/ha for fresh chilli fruits and a total of 56.5 kg of Clarias fish for one season.

Introduction:

Because of the unpredictability of fishing seasons and a decrease in fish catches due to the impacts of climate change, marine fishing communities in Benin have a growing interest in diversifying their livelihoods. Simultaneously, these communities are also grappling with the decrease in agricultural production due to the salinity of underground water used for irrigation. However, potentials in the agricultural and aquaculture sector, technical innovations in irrigation and sustainable soil management are unknown to the participants in the fishing sector.

A study in mainly fishing communities, as documented in 2008[5], revealed that these communities enjoy a relatively satisfactory food diversity and security. However, households who depend mainly on market gardening for their livelihoods have better food security than fishing households, and more frequently consume leafy vegetables.

There are strong gender issues encountered in the ongoing livelihoods diversification within the fishing sector, which have to do, among other things, with the allocation of gardening work to women without them having any power on the use of the revenues thereof. The majority of men prefer keeping to their fishing activities, therefore diversifying revenues with other activities becomes women's affair[6].

Supporting fishing communities to enable them to diversify their activities in terms of market gardening and rice-fish production is essential to boost their food security and diversity.

Materials and methods

Two studies were conducted:

1. Rice production study: It was decided to test rice production in the Hio area (Ouidah commune) where rice has never been produced before. Therefore, in 2008, the youth of these households were involved in rice cultivar tests in order to identify ideotypes and cultivars that are most adapted to the types of soils through an assessment of their agro-morphological characteristics, resistance to diseases and insects, water table fluctuations, and salinity tolerance. A total of 44 rice cultivars, including 12 rain-fed cultivars and 32 lowland cultivars were tested.

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[5]Food security and nutritional situation in 4 mainly fishing communities in Benin; Maylis Razes, Marie Claude Dop ; Katrien Holvoet and Pierre Coffi Galo; FAO Fishing and HIV/AIDS Programme in Africa; 2010
[6]Study on the irrigation systems used in market gardening in Southern Benin and their impact on the competitiveness of the sector ; Chrysogone K. Kassegne; Denis Gnakpenou, IFAD 2014
[7]Toward Sustainable Clusters in Agribusiness through Learning in Entrepreneurship (2SCALE) is a project funded by the DGIS and executed by IFDC
[8]The NIKLY variety is produced by East West Seed International (EWIT), a partner of 2SCALE
[9]The products used are licensed in Benin and authorised for market garden crops such as Pacha 25 EC and Acarius 18 EC
[10]Confirmed by other producers who received fingerlings from the same fish farmer at the same time with similar results
[11]The daily average gain increased from 0.96g to 4.31g and 4.2 g

The participation of the women started at the field observations of the rice varieties till the final step on organoleptic appreciation of the best performing varieties. Women gave feedback to the community as shown in Plates 1 and 2.

Plate 1: Rice: actors' assessment

Plate 2: Female youth giving feedback to the community on the rice trial

2. Chili pepper production study: In Grand-Popo, IFDC through their programme 2SCALE[7] has since 2012 been conducting learning activities for beneficiaries in the chili pepper production sector and identified chili pepper cultivars that are (i) performing best, (ii) are adapted to the ecological environment, and (ii) have an easy access to the market. They introduced techniques for soil fertility management, nursery establishment and management, nursery bed preparation, nematode management, the use of anti-insect netting, best practices for transplanting, harvesting, drying, storage and processing chili into powder and the use of best irrigation practices.

The youth of the Ayiguinou Association received training in sustainable management practices and chose the NIKLY cultivar, which is a hybrid and hotter cultivar, for the action-research. Its fruits resemble those of the local cultivar which is already appreciated in the market. The fruits of NIKLY[8] are relatively long and can quickly fill the basket used as a measurement unit in the area.

The efficiency (irrigation duration, moisture depth in the soil, water volume) and the cost effectiveness (cost of fuel for the water pump, water volume) of the following irrigation systems were compared

a. Micro spray irrigation
b. Irrigation with flexible pipes, the most widespread technique in the area
c. Drip irrigation with water from an 8 m deep borehole
d. Drip irrigation with irrigation water from aquaculture tanks used for the production of cat fish (*Clarias gariepinus*). This system is being promoted by the Fishery Production Directorate of Benin (Plates 3 and 4).

Plate 3: Action-research chili

Plate 4: Combination of market gardening with aquaculture tanks

The water input for the aquaculture tank where Clarias are produced, comes from the same source as the water for the drip irrigation of crops. The Clarias were fed with provender

(17% protein content) twice a day. Clarias are very resistant to stress caused by lack of oxygen, and has a growth (average daily gain) of 5 to 8 g/day, making it possible to have fish of commercial size within 4 to 5 months.

The youth of the association received training in the use of aquaculture tanks for the production of *Clarias gariepinus* before the start of the action-research. 165 fingerlings of 15 g were stocked a week before the transplanting of the chili and the start of the drip irrigation. The water level in the aquaculture tank did not drop more than 15 to 20 cm, being topped up as the irrigation proceeded.

The drip irrigation system consisted of round pipes of 16 mm diameter using internal tricklers distanced 20 cm from one another. The pipes were placed at a distance of 40 cm apart on the beds, making two lines per bed. The system included three water reservoirs: one 2 m^3 reservoir which is directly connected to the water source and two 1.5 m^3 reservoirs fed by the first reservoir. One of the 1.5 m^3 reservoirs served as aquaculture tank, supplying water to the drip irrigation system.

One week before the chili was transplanted, each bed of 3 m x 15 m received 50 kg of cow dung (about 11 t/ha). Two weeks after the transplanting, each bed received 2.66 kg of NPK (about 600 kg/ha), and one week later, urea was applied at a dose of 200 kg/ha. Phytosanitary[9] treatments were carried out in a systematic manner. Since the period of action-research coincided with the dry season during which the risk of fungal infection is low, only insecticides were used.

Results and Discussion

Rice production study: The highest yields were recorded by lowland rice cultivars, such as IR 4630-22-2, WAS175-B-21-4 and IR 69588-4RP-3-3, with yields higher than 5 tons per hectare, followed by rain-fed cultivars such as NERICA 4, NERICA 6 and NERICA 15, with yields higher than 3 tons per hectare.

Chili pepper production study: The micro spray system gave a higher yield (9 562 kg/ha) as compared to the drip system (7 880 kg/ha) and the flexible pipe (6 866 kg/ha). When water from the fish production system was used for the drip irrigation system, the yield increased to 10 691 kg/ha. This is 36% higher than the yield with drip using borehole water, but only 12% higher than with micro spray irrigation. These yields are those recorded after 7 successive harvests over a period of 7 weeks. These results are supported by the effect of the various irrigation systems on the average length and size of the fruits. The fruits harvested where fish production water was used were longer (12 cm) and bigger in size (1.10 cm diameter) while those for which flexible pipes were used were the smallest (10 cm and 1 cm length and diameter respectively).

Table 1 Chili yield and fruit size under different irrigation systems

Irrigation system	Chili yield parameters		
	Yield (kg/ha)	Fruit size (cm)	
		Length	Diameter
Micro spray	9 562	12	1.1
Drip with borehole water	7 880	11	1.0
Flexitubes	6 866	10	1.0
Drip with aquaculture water	10 691	12	1.1

Water consumption was lowest with the drip irrigation with 150 L per day being used. Micro spray used 286 L and the flexitubes 600 L per day. The combination of aquaculture and drip irrigation gave the lowest water consumption (140 L per day). The fuel consumption for the pump was not recorded but more fuel is used with the flexitubes and with the micro spray. Because of the larger quantities of water used by the micro spray and flexitube systems than by the drip system, the former two give lower water use efficiencies (in terms of kg of chilli produced per m3 water applied) (Table 2). Thus when comparing micro spray with drip irrigation using borehole water, the micro spray system would be best if available land was the most limiting factor and the drip system if available water was the most limiting factor.

Table 2. Chili yields, water used and water use efficiency under different irrifation systems

Irrigation system	Yield (kg/ha)	Water used (L/ha)	Water use efficiency (kg/M3)
Micro spray	9 562	63.500 L/ha/day	1.368
Drip with borehole water	7 880	33.300 L/ha/day	2.151
Flexitubes	6 866	133.300 L/ha/day	0.468
Drip with aquaculture water	10 691	31.300 L/ha/day	3.105

The higher yields obtained with the drip irrigation from aquaculture water (see Table 2) can be explained by extra organic matter and nutrients that are provided to the plants from the fish tank waste waters can be explained by the better retention of nutrients in the sandy soils due to the influence of the organic matter and less leaching of nutrients from these sandy soils that have low organic matter. Treatments with higher water use (as in micro spray and flexitubes) cause higher leaching of nutrients. This explains as well the more efficient use of irrigation water.

The aquaculture tank used for irrigation helps to achieve the best results for chili production and at the same time to have 56.5 Kg of fish (weight after 4 months).However, this low aquaculture result is due to the bad quality[10] of the fingerlings[11] and a 14% loss of them.

Acceptance and adoption of research outcomes: The rice varieties with the highest yields were used in a degustation and found suitable by the community. The research outcomes of the chili-fish production led to requests by other youths to receive a training in fish production and hatchery management.

Conclusions and recommendations

The male and female youth in marine fishing communities are facing the challenges of reduced catches and are eager to establish sustainable alterative or complementary income generating activities but they face major constraints Youth are mobile and migrate and have often higher education levels than their parents and are eager to explore new opportunities: they were the first to bring the micro spray technology to Grand Popo and understood from the cost-benefit analysis of crop systems that there is a need to combine better agricultural practices and water management. Factors hampering or preventing the youth to be innovators are part of the gender concerns (youth and women) such as their access to financial capital to pay for the investments and their access to land.

The future interventions should focus on a dialogue on gender concerns and on both cash crops (chilly pepper) and food crop (rice) that can be combined with aquaculture and would be a complementary activity that would as well be contributing to the strong position women have in fish processing and marketing in the marine fishing communities.

Diversification in the chilli peppers and market gardening is also improving the access to other vegetable production such as leaf vegetables, tomatoes and local traditional vegetables which are part of the rotation in the market gardening. The practice could contribute to the nutrition security at the household level and contribute to reducing the chronic malnutrition of children under five years old in marine fishing communities.

Promotion of rice-fish and vegetable-fish production in the marine fishing communities should be strengthened. Water efficient and environmental sound production systems are available and should be taught and should result in increased income and access to vegetables and fish as a protein source.

Diversification initiatives take into account a reduction in the workload of women, equality in the management of income and the provision of technologies to help (i) combine aquaculture with agricultural production, (ii) reduce watering time, (iii) practice a sustainable water management and, (iv) use inputs (fertilisers and pesticides) efficiently.

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Watershed management technologies to boost the resilience of Cabo Verde to climate change, and to mitigate the effects of desertification

Jacques de Pina Tavares[1]

Summary

Desertification, due to recurrent droughts and soil degradation, constitutes the major cause of the degradation of the ecological fabric, and poverty in Cabo Verde. In order to boost the resilience of the archipelago and ensure quality life for its people in the midst of this phenomenon, a whole soil and water conservation arsenal has been tested on the major watersheds and watercourses of agricultural lands. Reforestation, hydraulic structures, drip irrigation, improved species and the involvement of communities are key steps to reclaim these lands in the Sahel region. This approach has resulted in more than 20% of the territory being reforested, 10,000 ha of farmland reclaimed and used, a strong mobilisation of surface waters with the building of several hydro-agricultural dams on the main agricultural islands, and finally a significant improvement in the productivity of irrigated lands. Certainly, spectacular results have been recorded over the past 40 years, but this initiative is still ongoing as rain-fed agriculture, which mobilises 90% of cultivated lands and the majority of soil and water conservation technologies, is still lagging behind irrigated agriculture, precipitations are unreliable and soil erosion is still wreaking havoc in ecosystems.

1. Introduction

The Cabo Verde archipelago is a small island state in the Sahel region. It has a surface area of 4,033 km^2, and is located about 500 km from the Senegal-Mauritania coasts. The country is made up of 10 islands and several volcanic islets (Figure 1). It was uninhabited until it was discovered in the 15th century (1462) by the Portuguese. Currently the population is about 500,000. The climate varies from sub-tropical arid to semi-arid. The average annual precipitation is about 230 mm, with significant disparities among the islands (13 mm in Sal as compared to 323 mm in Santiago). There are no permanent water sources in Cabo Verde. The volcanic soils on slopes and tablelands, mostly used for rain-fed agriculture, are underdeveloped, poor in organic matter (< 2%) but rather rich in mineral nutrients. However, those on valley floors are very deep and rich in organic matter.

Figure 1: Geographical location of Cabo Verde

The degradation of the ecological fabric of the archipelago through desertification started almost a century after it was discovered and populated, resulting in a dire shortage of water and fertile arable lands. This has an adverse effect on food security, biodiversity, and has worsened the vulnerability of the population. To remedy this situation, a whole arsenal of measures and soil and water conservation structures have been introduced and tested. These interventions have been modelled with watershed areas depending on the complexity of the topography and the diversity of bioclimatic zones. This study aims to sum up these protection measures and assess their impacts.

2. Reforestation

Successive and recurrent droughts, coupled with anthropogenic pressure on natural resources, have led to a considerable decrease in the vegetative cover. When Cabo Verde became independent in 1975, only about 5,000 ha of land were afforested as compared to 89,000 ha currently (Figure 2), thanks to the momentous efforts made by the state with the support of the international community and the strong mobilisation of the civil society. The main woody species planted are: prosopis sp. (61 %) and acacia sp. (6.3 %).

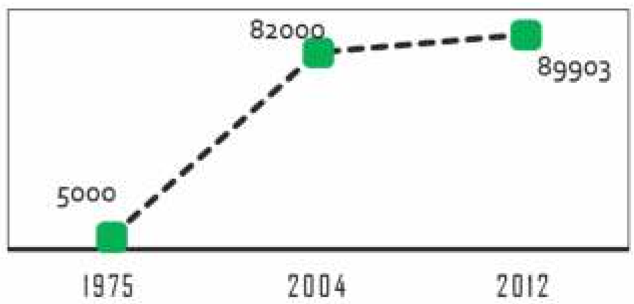

Figure 2: Trend in afforested areas over time (ha)

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3. Live vegetative barriers

Live vegetative barriers are used on a range of the most arid to the most humid slopes, along elevation contours, from the top to the base of slopes. Their biophysical and socioeconomic impacts are considerable and numerous (Table 1).

Table 1: Plant species used as live barriers and their effects on the soil

Plant species	Effects on soil qualities				
	Soil fertility	Fodder production	Maize production	Water infiltration	Sedimentation* (cm.yr-1)
Aloe vera	Fairly high	None	High	Excellent	2.75
Leucaena leucocephala	Very high	Very high	Very high	Good	1.85
Cajanus cajan	Very high	Fairly high	Very high	Good	1.70
Furcraea gigantea	Fairly high	None	Fairly high	Good	-
Prosopis juliflora	Very high	Fairly high	Low	Good	-

** The sedimentation corresponds to the retained soil behind the live vegetative barriers.*

4. Main watershed management and torrent control structures

To ensure the establishment of arborized species, stabilise watershed soils and improve the yield of rain-fed crops, several techniques have been employed (Table 2). The main objectives are to harness rainwater, to replenish groundwater and reduce the destructive force of surface run-off..

***Table2:** Main land management techniques*

Technique	Ecosystem where used	Impacts		Installation cost	Durability and scale of impact
		Soil stabilization	Runoff reduction		
Contour ridges	Slopes	Low	Good	Acceptable	Long term /high
Half-moons	Slopes	Low	Good	Acceptable	Long term/moderate
Contour stone walls	Slopes	Good	Fairly good	High	Medium term/high
Bench terraces	Slopes	Very good	Good	Very high	Long term/Moderate
Check-dams	Watercourse	Very good	Very good	Very high	Short term/high
Dry stone flood barriers	Watercourse	Very good	Very good	High	Short term/high
Gabion flood barriers	Watercourse	Very good	Very good	High	Short term/moderate
Dry stone walls	Watercourse	Good	Low	High	Medium term/moderate

5. Main water storage technologies

On average, 78 % of water consumed in Cabo Verde comes from groundwater, and the remaining 22% is desalinated sea water. Some of the islands, such as Sal and São Vicente, are largely served with desalinated sea water at the rates of 100 and 58% respectively (Table 3). Rainwater is also harnessed by means of rainwater cisterns where rainwater is directly harvested from the roofs of houses. This technique is widespread on the Fogo Island. There is also another form of harvesting and channelling rainwater locally known as "espelho de captação". This system is made up of three elements: an impluvium made with bricks and cement on a slope which is used to harvest the water, then this water is channelled to a downstream reservoir through a channel.

Table3: *Proportions of various sources of water used on different islands*

Island	Proportion of water used from different sources (%)			
	Underground	Desalinated	Treated wastewater	Surface runoff
Santo Antão	98	2	0	0
São Vicente	29	58	13	0
São Nicolau	100	0	0	0
Sal	0	100	< 1	0
Boa Vista	88	12	0	0
Maio	100	0	0	0
Santiago	87	10	< 1	3
Fogo	100	0	0	0
Brava	100	0	0	0

Source: *Adapted from PENAS (2013)*

6. Impacts of land management and water mobilisation technologies

The stabilization of watershed soils and torrent control in watercourses has helped to create, rehabilitate and reclaim close to 8,000 ha of rain-fed farmland and more than 2,000 ha of irrigated farmland (Error! Reference source not found.). This way of adding value to land plays an important role in the food security of rural families because about 45% of the population live in rural areas.

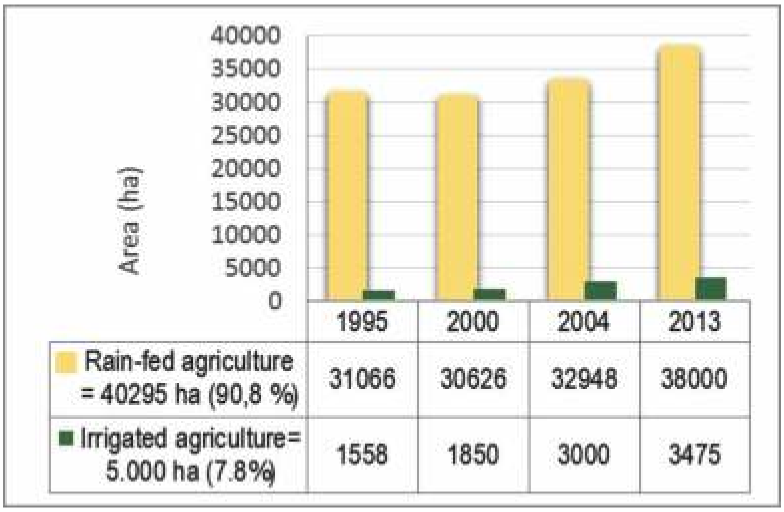

Figure3: *Increase in cultivated land areas from 1995 to 2013 (ha)*

This increase in cultivated area, together with the improved water conservation measures, has helped to significantly improve in less than 13 years the production of fruit from 10,000 tons to more than 16,000 tons, vegetables by more than 300% and market garden products from 5,651 to 44,180 tons (Figure 4). Grape production has increased nearly fourfold in ten years, from 104 tons in 2004 to 385 tons in 2014 (Ministry of Rural Development Report , 2015). These results have enabled the people of the archipelago to have these products throughout the year on the market, which was not possible in the early 1990s.

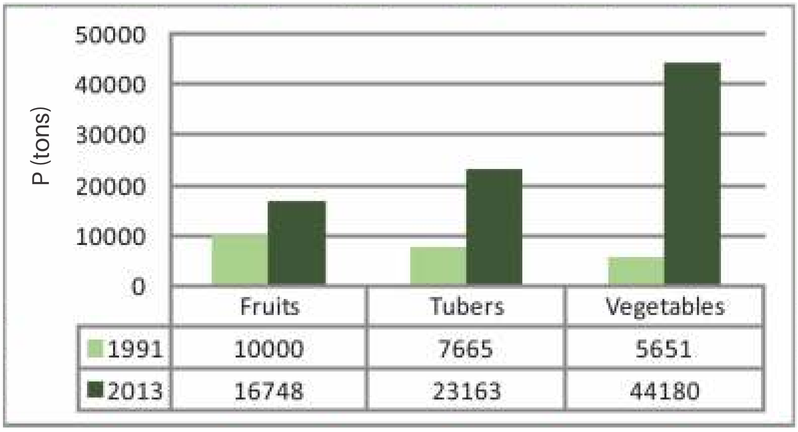

Figure 4: *Increase in the production on irrigated lands between 1991 and 2013 (tons)*

More than 90 % of irrigation water is from underground sources, notably springs, wells, boreholes and galleries in the proportions of 43.7, 25.8, 17.9 and 3.6 % respectively (RGA, 2004). To reduce the pressure on these sources, a strong surface water mobilisation policy has been put in place since the early 2000s, capturing 78% of the investment programme (MDR, 2015b). According to the hydrological balance, about 87 % of these waters (180.10^6 m^3 per year) run off into the sea where they are lost through evaporation. From 2006 to 2015, more than ten hydro-agricultural dams capable of mobilising about $250.\ 10^6$ m^3 water for irrigating more than 400 ha of land were built. At the same time, other technologies such as drip irrigation and crop cultivars more adapted to arid conditions were approved for usage (INIDA, 2014). Glasshouse crops, improved animal races, and plant protection solutions that are simpler and more accessible to farmers have also been approved for use. However, the heavy dependence on rain-fed agriculture and current rainfall patterns have slowed down results achieved (Figure 5) even though the many soil and water conservation technologies have been developed.

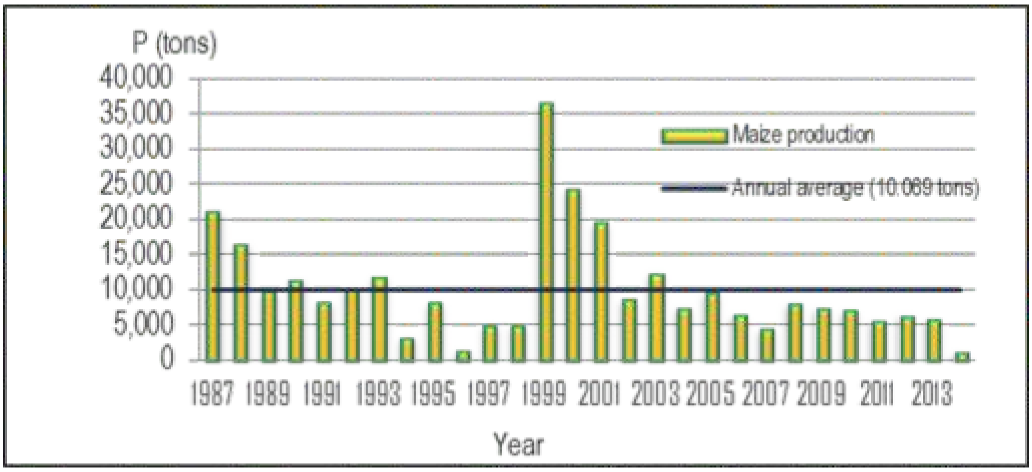

Figure 5: *Variation in maize production over (tons). Adapted from Ministry of Rural Development Report, 2015*

7. Conclusions

The tremendous water conservation and land reclamation efforts made by Cabo Verde since its independence in 1975 have produced very encouraging results in the recovery of the ecological fabric of these Mars-like islands. Droughts had taken a huge toll on the population by decimating more than half of it. Those who fled the country found refuge in other countries in Africa, the United States and Europe. Today, although droughts still persist, their adverse effects are almost non-existent. After centuries of unwavering fight against harsh and complex weather conditions, Cabo Verde has recently been able to find some solutions or technologies needed to deal with the scarcity of arable land and water, and ensure the well-being of the people. However, the country is still grappling with the quest for cultivated lands, and the problems of soil erosion, scarcity of rains, the pressure on underground waters, the salinity of some ground waters, and fodder scarcity.

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2015 International Year of Soils

Key messages on soils from the Forestry Department of Food and Agriculture Organization of the United Nations

1. Climate change: what forests and forest soils do

Carbon emissions are a major contributor to climate change. The world´s forests, in one of their many roles, act as a significant carbon store. 650 billion tonnes of carbon, or nearly one third of the total in terrestrial ecosystems, are captured in forests. Forest soils also store a quantity of carbon equalling that of the global forest biomass, about 45 percent each. An additional ten percent of carbon is found in forest dead wood and litter. In total, forests store as much carbon as the atmosphere.

2. Sustainable soil management needs sustainable forest management, including restoration

The planet needs sustainably managed forests to control soil erosion and to conserve soil. Tree roots stabilize ridge, hill and mountain slopes and provide the soil with the necessary mechanical structural support to prevent shallow movements of land mass: landslides rarely occur in areas with high forest cover.

Sound forest management practices, including measures to introduce or maintain forest cover on erosion-prone soils and run-off pathways, will help control or reduce the risk of soil erosion and shallow landslides. Forest restoration in dryland areas is vital for soil protection.

3. Major ecosystem benefits of forests and soils: clean water and watershed management

By reducing soil erosion and the risk of landslides and avalanches, sustainably managed forests contribute significantly to the systems providing and maintaining the planet's supplies of clean water, while also ensuring a balanced water cycle. Forests are also a key component of watershed management – an integrated approach of using natural resources in a geographical area drained by a water course. Watershed management is a very sound way to protect and rehabilitate areas prone to soil degradation and erosion in upland areas. Forest and soil characteristics are among the key parameters assessed in watershed management planning. Moreover, measures to restore and enhance soil fertility, e.g. through reforestation, have many benefits and are therefore an integral part of any watershed management plan.

4. Soil conservation in semi-arid and arid areas starts with forests and trees

By helping to prevent soil erosion, forests act as a crucial protector of soil resources, for example in preventing or reducing salinization. The challenge in arid-zone forests is therefore to optimize the trade-offs, between water yield and soil protection.

5. Forests can reduce mountain soils' sensitivity to degradation

Steep slopes and thin soil make mountain ecosystems extremely vulnerable to erosion. Mountain soils are often degraded and invariably do not provide enough nutrients for plants to grow well. FAO estimates that around 45 percent of the world's mountain area is not or only marginally suitable for agriculture. The degradation of mountain soil and vegetation cover may happen gradually or rapidly but often takes many years to repair; in some cases it is irreversible.

The challenges that mountain farmers must overcome are many: short vegetation periods, steep slopes, shallow soils and the occurrence of landslides. To survive, they have had to develop different ways of averting or spreading risks, employing complex and diversified farming systems on croplands, pastures and forests. They know that they must make use of different soil types at different altitudes and at different times of the year.

Source *:* *http://forestry.fao.msgfocus.com/files/amf_fao/project_59/April_2015/Soils_Key_messages_revisions_Thomas20April_Final_clean_.pdf*

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Promoting sustainable soil management in sub-saharan Africa through the African Soil Partnership

Liesl Wiese[1], Craig Chibanda[2], Victor Chude[3], Ronald Vargas[4] and Lucrezia Caon[5]

Summary

In Sub-Saharan Africa, soil degradation leads to a massive annual loss of productive soils and is the root cause of declining agricultural productivity. If soil degradation is allowed to continue, it will have severe negative impacts on the economies of individual countries and the welfare of millions of rural households dependent on agriculture for their livelihoods. The Global Soil Partnership (GSP) was established in 2012 to promote sustainable soil management (SSM) at all levels. Regional Soil Partnerships were established in order to facilitate regional actions and to ensure that the partnership process becomes country driven. The Steering Committee of the African Soil Partnership (AfSP) identified priorities for SSM promotion and implementation under the five Pillars of Action of the GSP. The International Year of Soils has triggered various actions at regional and national levels, for instance regional and national workshops were organized as well as many other social and educational activities. The implementation of the GSP plans of action will focus on SSM in the region for the purpose of fighting hunger and poverty, adapt and mitigate to climate change and ensure the provision of other ecosystem services by soils (e.g. clean water). However, soil degradation remains an issue in the region, which is in need of further support from the GSP and the international community. Investments in SSM and soil and land rehabilitation are seen as the only solutions to improve soil health and therefore the welfare of millions of people.

Introduction

To feed its growing population, Sub-Saharan Africa (SSA) is intensifying and expanding its agricultural production (Tully et al., 2015). However, the region has the lowest agriculture and livestock yields of the world due to soil degradation (IFAD, 2009). Soil degradation is defined as "the diminishing capacity of the soil to provide ecosystem goods and services as desired by its stakeholders" (FAO and ITPS, 2015). It manifests in various forms such as the loss of organic matter and adverse change in salinity, acidity or alkalinity (Tully et al., 2015). Soil degradation is specifically recognized by both policy makers and soil specialists as one of the root causes of declining agricultural productivity in the region where 75 percent of the population depended on subsistence farming at the end of last century (Lal, 1990; Tully et al., 2015; UNEP, 1982). Should this trend be allowed to continue, the effect on the economies of individual countries and the welfare of millions of rural households dependent on agriculture for their livelihoods will be severe (FAO, 1999).

One of the main obstacles to reducing land degradation, improving agricultural productivity and facilitating the adoption of sustainable soil management (SSM) among smallholder farmers is the lack of information and knowledge (FAO, 2011). Up to date there are not reliable data on the extent and rate of soil degradation in SSA (Tully et al., 2015), however it has been estimated that an area of five to eight million hectares of formerly productive land goes out of cultivation annually due to degradation globally (TerrAfrica, 2007). In order to reverse soil degradation it is important to develop indicators to estimate and monitor the status of soil health and promote SSM (Tully et al., 2015). The objective of this paper is to discuss the progressive adoption of SSM in SSA through the African Soil Partnership (AfSP) and the way forward to curb soil degradation in the region.

The Global Soil Partnership

The Global Soil Partnership (GSP) was established and formally endorsed by FAO member countries in 2012 to create a unified and recognized voice for promoting SSM at all levels. Therefore, the establishment of the GSP relies on the need to have an international governance body advocating for SSM in global change dialogues and decision making processes. In order to achieve its objectives, the GSP addresses 5 pillars of action: (1) promote sustainable management of soil resources for soil protection, conservation and sustainable productivity, (2) encourage investment, technical cooperation, policy, education awareness and extension in soil, (3) promote targeted soil research and development focusing on identified gaps and priorities and synergies with related productive, environmental and social development actions, (4) enhance the quantity and quality of soil data and information, and (5) harmonization of methods, measurements and indicators for the sustainable management and protection of soil resources.

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In order to facilitate regional actions, Regional Soil Partnerships were established among interested and active stakeholders with the aim of building on existing regional networks or collaborative processes, linking national and local networks, partners, projects and activities to ensure that the partnership process becomes country driven (FAO, 2015a).

One of the core activities of the GSP has been the revision of the World Soil Charter (WSC) of 1981 by the Intergovernmental Technical Panel on Soils (ITPS) (FAO, 2015b). The need to revise the WSC was identified to adjust the focus of the document from land use planning and land evaluation (FAO, 1982) to key concepts such as the framework of ecosystem services provided by soil. The revised version of the WSC was endorsed during the 39th FAO Conference in 2015 as a vehicle to promote and institutionalize sustainable soil management at all levels (FAO, 2015c). 2015 is important to soils especially because it was declared the International Year of Soils (IYS) by the 68th UN General Assembly (A/RES/68/232) for the purpose of serving as platform for raising awareness of the importance of soils for food security and essential eco-system functions under the GSP framework (FAO, 2015d). According to FAO (2015d), the objectives of the IYS are (i) to create full awareness by civil society and decision makers about the fundamental roles of soils for human's life, (ii) to achieve full recognition of the prominent contributions of soils to food security, climate change adaptation and mitigation, essential ecosystem services, poverty alleviation and sustainable development, (iii) to promote effective policies and actions for the sustainable management and protection of soil resources, (iv) to sensitize decision-makers about the need for robust investment in sustainable soil management activities aiming at healthy soils for different land users and population groups, (v) to catalyze initiatives in connection with the SDG process and Post-2015 agenda, and (vi) to advocate rapid enhancement of capacities and systems for soil information collection and monitoring at all levels (global, regional and national).

At the United Nations Sustainable Development Summit on 25 September 2015, world leaders adopted the 2030 Agenda for Sustainable Development and therefore endorsed a set of 17 Sustainable Development Goals (SDGs) to end poverty, fight inequality and injustice, and tackle climate change by 2030 (UNDP, 2015). For the first time in history, soils were included and explicitly mentioned in the development agenda:

- Goal 2, target 2.4: "by 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality";

- Goal 3, target 3.9: "by 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination";

- Goal 15, target 15.3: "by 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land-degradation-neutral world" (UNDP, 2015).

This is considered a great achievement in the way forward toward the broad adoption of sustainable soil management.

The African Soil Partnership

It was decided to establish eight regional soil partnerships under the umbrella of the GSP with the task of provide guidance on regional goals and priorities (FAO, 2015f). North African countries (Algeria, Egypt, Libya, Morocco, Sudan and Tunisia) respond to the Near East and North Africa Soil Partnership. Thus, the African Soil Partnership includes only countries in Sub-Saharan Africa.

The African Soil Partnership (AfSP) was launched in Western and Central Africa in March 2013 (Accra, Ghana), and in Eastern and Southern Africa in April 2013 (Nairobi, Kenya). The AfSP was then consolidated at the first African Soil Partnership (AfSP) Workshop in May 2015 (Elmina, Ghana). During the Elmina workshop the AfSP Steering Committee was established for guiding AfSP implementation and the Elmina Communiqué was compiled in order to consolidate the institutional mechanism of the AfSP, list the intentions of the Partnership in terms of addressing sustainable soil management and related issues in the region, and commit to completing the Implementation Plan for the region (FAO, 2015e).

The AfSP and a range of national and regional partners of the GSP are currently developing a regional Implementation Plan for the purpose of setting the priorities and medium term outcomes and activities for the SSA region. Priorities for SSM in the SSA region are developed under the umbrella of the five Pillars of Action of the GSP and rely on the definition of SSM as proposed by the revised WSC (FAO, 2015c). Therefore, priority is given to (i) assess and document soil degradation status and trends, the potential for agriculture for major agro-ecological zones, land use systems and existing SSM practices, (ii) develop a monitoring system to measure progress of implementation of SSM practices and systems, (iii) upscale proven successful SSM practices, (iv) establish and strengthen National Soil Science Societies in all countries/sub-regions, (v) revitalize the African Soil Science Society and its website for active information sharing, (vi) create Sustainable Soil Management partner platforms, (vii) develop regional exchange programmes for tertiary soil science training, along with an associated bursary scheme, (viii) repackage soil information for extension programmes, (ix) propose region-specific policies and strategies that countries can adopt, (x) develop a website/page for research and development priorities, (xi) assess and prioritize soil-related research gaps, (xii) set up regional working groups for specific research themes with clear terms of reference, (xiii) establish African Soil Research for Development Platforms, (xiv) document soil data sources and soil mapping covariates, (xv) develop a comprehensive soil database and an online interaction platform for digital soil mapping (DSM), (xvi) conduct DSM training and capacity building, (xvii) produce digital maps of soil texture as initial digital mapping products for the region, (xviii) regularly update soil databases, (xix) develop a common harmonization concept for soil description and classification at regional level, (xx) GSP/FAO to revitalize the regional soil correlation events that used to be organized, (xxi) identify national, regional and international reference laboratories for training, soil analyses and soil sample exchange, and (xxii) develop a framework to indicate how individual country or regional soil data can be shared with others.

Conclusion

Sub-Saharan Africa is affected by different forms of soil degradation that lead to a massive annual loss of productive soils and are the root cause of declining agricultural productivity in the region. If soil degradation is allowed to continue, it will have severe negative impacts on the economies of individual countries and the welfare of millions of rural households dependent on agriculture for their livelihoods. Through the establishment of the GSP and therefore the activities promoted at national and local level by the AfSP, much was done to sensitize the population on the importance of preserving and improving soil health and on the need to adopt sustainable soil management in order to fight poverty and hunger. However, the many projects and activities launched in the region since the establishment of the partnership were not sufficient to tackle the numerous problems affecting sub-Sahara African soils. Soil degradation remains an issue in the region, which is in need of further support from the GSP and the international community. Investments in sustainable soil management and soil and land rehabilitation are seen as the only solutions to improve soil health and therefore the welfare of millions of people.

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Five reasons why soil is key to the planet's sustainable future

1. Healthy soil feeds the world

Soil is where food begins. Composed of minerals, water, air and organic matter, soil provides primary nutrient cycling for plant and animal life and acts as a basis for feed, fuel, fibre and medical products as well as for many critical ecosystem services.

To explore further visit: http://www.fao.org/soils-2015/en/

2. Soil, like oil or natural gas, is a finite resource

Soil is non-renewable – its loss is not recoverable within a human lifespan. It can take hundreds to thousands of years to form one centimetre of soil from parent rock, but that centimetre of soil can be lost in a single year through erosion. Poor farming practices - extensive tilling, removal of organic matter, excessive irrigation using poor quality water and overuse of fertilizers, herbicides, and pesticides - deplete soil nutrients faster than they are able to form, leading to loss of soil fertility and degrading soils. Some experts say the number of years of top soil left on the planet is comparable to estimates for reserves of oil and natural gas. At least 16 percent of African land has been affected by soil degradation. And globally, 50,000 square kilometres of soil, an area the size of Costa Rica, is lost each year, according to the Global Soil Partnership. For further information on Global Soil Partnership visit: http://www.fao.org/globalsoilpartnership/en/

3. Soil can mitigate climate change

Soil makes up the greatest pool of terrestrial organic carbon, more than double the amount stored in vegetation. As well as helping to supply clean water, prevent desertification and provide resilience to flood and drought, soil mitigates climate change through carbon sequestration and reduction of greenhouse gas emissions. "Soils of the world must be part of any agenda to address climate change, as well as food and water security," says Rattan Lal, Director of Ohio State University's Carbon Management and Sequestration Center" For more about Carbon Management and Sequestration Center visit: http://cmasc.osu.edu/pageview2/Home.htm

4. Soil is alive, teeming with life

A quarter of the planet's biological diversity exists in soil. There are literally billions of microorganisms such as bacteria, fungi, and protozoans in the soil, as well as thousands of insects, mites and worms. More organisms are contained in one tablespoon of healthy soil than there are people on the planet. "It's only been recently that we've begun thinking about soil biodiversity as a resource we need to know something about," says Diana Wall, Scientific Chair of the Global Soil Biodiversity Initiative. "Without soil and their biodiversity, there is no human life." Further information about the Global Soil Biodiversity Initiative on: https://globalsoilbiodiversity.org/

5. Investing in sustainable soil management makes economic and environmental sense

Managing soil sustainably is cheaper than rehabilitating or restoring soil functions. A FAO-led project focusing on land, water and biological resources to reverse the process of land degradation in the Kagera river basin between Burundi, Rwanda, Uganda and Tanzania has improved the livelihoods and food security of farmers around Lake Victoria. To access State of the Art Report on Global and Regional Soil Information follow the link: http://www.fao.org/fileadmin/user_upload/GSP/docs/report/Soil_information_Report.pdf

Further information about soils can be found at: http://www.fao.org/post-2015-mdg/news/detail-news/en/c/277113/

African Soil Partnership

A 3-day workshop on the Africa Soil Partnership (AFSP) jointly organised by the Global Soil Partnership and the FAO Regional Office for Africa, took place from the 20-22 May 2015 at the Coconut Grove Beach Resort, Elmina. Ghana. The workshop was attended by participants from 35 Subsaharan Africa countries. Opening the workshop Mr. Bukar Tijani (Assistant Director-General/Regional Representative for Africa, Regional Office for Africa, United Nations Food and Agriculture Organization) challenged participants to perceive the workshop as a platform to give voice to the critical issues at stake. He added that from the Abuja Declaration of 2006 a lot needs to be done - identifying existing gaps and sharing ideas on innovative ways to move forward.

Participants meet at Elmina, Ghana to form the African Soil Partnership, May 20-22, 2015.(Photo courtsey David Young)

Mr Thiombiano the moderator for the workshop remarked that if the world is celebrating the International Year of the Soils, it is because it is gradually coming to the realisation that indeed the soil is a vital resource without which life cannot continue. The declaration of 5th December each year by the UN General Assembly as World Soil Day shows that increasingly the world is coming to see the dynamic role that soils plays especially in the fight against climate change and maintaining a sustainable environment. He added that there is a bright opportunity for soil scientists to make sure they take advantage of the current platform to give soils the much needed recognition.

Mr Ronald Vargas from United Nations Food and Agriculture Organization headquarters in Rome emphasized the need for a strong partnership for Africa. He explained that the mandate of the Global Soil Partnership is to improve governance of the limited soil resources of the planet in order to guarantee healthy and productive soils for a food secure world, as well as support other essential ecosystem services, in accordance with the sovereign right of each State over its natural resources. He stressed the need for inclusive policies and governance, investment in sustainable soil management targeting soil research and capacity building especially training younger people.

National presentations were made on the status, needs and priorities for sustainable soil management in sub-Saharan Africa (SSA). Soil erosion, land degradation, poor capacity building, inadequate soil information and lack of harmonisation were identified among the challenges facing soil resource management in SSA. The workshop also supported the finalisation of a draft regional implementation plan. In all five working groups were formed to look at identifying activities that would fit into the Five Pillars of Actions by the GSP.

The establishment of a steering committee and its terms of reference were seen as a great milestone for the partnership. Two people were selected from each sub region and two others to represent the International Institute of Tropical Agriculture (IITA) and the African Soil Science Society (ASSS). Professor Victor Chude was appointed as the chair of the committee. To facilitate activities of the AFSP, FAO regional office for Africa volunteered to host the secretariat. Mr Brahene Sebastian (Sebastian.Brahene@fao.org) and Ms Liesl Wiese (WieseL@arc.agric.za) were appointed to be in charge of the secretariat.

Nominated members of the Steering Committee of the Africa Soil Partnership (Photo courtsey David Young)

The issuing of the Elmina communiqué was seen as a very important step in communicating to the world, Africa's preparedness to take up the challenges that threaten soil resources and also to encourage governments and other stakeholders to honour their commitments to support SSA to deal with the challenges of climate change which threaten agriculture and livelihood.

Information on the workshop can be obtained from: http://www.fao.org/globalsoilpartnership/highlights/detail/en/c/288450/

http://www.fao.org/globalsoilpartnership/regional-partnerships/africa/en/

Food forests could help end hunger for nomads in arid East Africa

Training Samburu pastoralists (northern Kenya) to grow forests—food forests

Full article at link, https://www.takepart.com/article/2015/08/25/pastoralists-drought-food-forests

Some extract:

In drought-ravaged Samburu County, 80 percent of the population lives below the poverty line. But it's on this semiarid landscape that Aviram Rozin, founder of Sadhana Forest is training Samburu pastoralists to grow forests—food forests. Designed to emulate the layered ecology of a natural forest, a food forest is made of seven layers hat range from tall trees to short shrubs, each working in support of the others. In Samburu County, these forests are planted with 18 species of drought-resistant, fruit-bearing indigenous trees and shrubs, including African oak, the fruits of which are said to be rich in protein and iron, and moringa,known locally as "mother's helper" thanks to its fruit, which helps stimulate milk production in lactating mothers and reduces malnutrition among infants. Sadhana Forest has trained more than 1,000 people in this low-tech approach to agriculture since it launched its Kenya operation in May 2014.

As long as we value a dead tree more than a tree that's alive we are in trouble.

Source: Paul Polman tweet @wemeanbusiness

Paul Polman @PaulPolman

info@twitter.com

Reforestation conference Accra, Ghana
16-17 March 2016

It's time for hands on to remove barriers and dramatically boost reforestation

Reforestation and landscape restoration as means of combating climate change are now high on the agenda of many governments and organizations, especially in the wake of COP21 in Paris. **Close cooperation between businesses and investors is needed** to meet this challenge and to develop plantation forestry into a stable and sustainable business that will be beneficial to all involved. The opportunities for all stakeholders are huge. A number of projects are already in place, and initiatives such as AFR100 are demonstrating a strong commitment, but the pace and scale of operations is still far too low to reverse forest loss.

The successful creation of new forests requires close, long-term commitment and cooperation between all parties. It is for this reason that we have set up a working conference on March 16 and 17, 2016 in Accra, Ghana. The conference is part of the initiative 'Forests for the Future – New Forests for Africa' which aims at large scale reforestation in Africa. As finance is a key enabler the conference will have a strong focus on the financial aspects of reforestation. We are proud to announce that one of our **keynote speaker will be the Honorable Mr. Kofi Annan**, Chairman of the Kofi Annan Foundation.

The conference is on invitation only and based on the impact attendees can and will have on reforestation in Africa. If you believe you should be participating in the conference, please send an e-mail with your personal details and reason for attendance to: info@newforestsforafrica.org

For more information (program, etc.) visit: http://newforestsforafrica.org

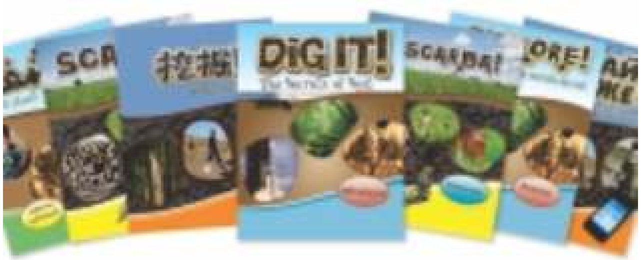
Twentieth Session of the African forestry and wildlife commission, Nairobi, Kenya.
1-5 February 2016

At the kind invitation of the Government of the Republic of Kenya, the Twentieth Session of the African Forestry and Wildlife Commission (AFWC) and the Fourth African Forest and Wildlife Week (AFWW) will be held at the Kenyatta International Conference Centre, in Nairobi, Kenya from 1st to 5th February 2016. The theme selected for the Twentieth Session and the Fourth African Forestry and Wildlife Week is "Sustainable Management of Forests and Wildlife in Africa: Enhancing Values, Benefits and Services". The theme has been purposely selected with AFWC bureau members to highlight and implement the many facets of sustainable management of forestry and wildlife, and to fully capture their importance in sustaining the livelihood of millions of people, and in contributing, in general, to sustainable development in the region. The AFWW will be held simultaneously with the Commission Session. Its purpose is to further draw the attention of policy makers and the public to the contribution of forests and wildlife to the national economy and the improvement of the livelihoods of the populations and, therefore, the need to give better recognition to forestry and wildlife in the broader national development agenda. The Week will include several exhibitions and side events.

International compost awareness week
1-7 May 2016

International Compost Awareness Week (ICAW) is the largest and most comprehensive education initiative of the compost industry. It is celebrated each year in the first full week of May. For more details follow the link: http://compostingcouncil.org/icaw/

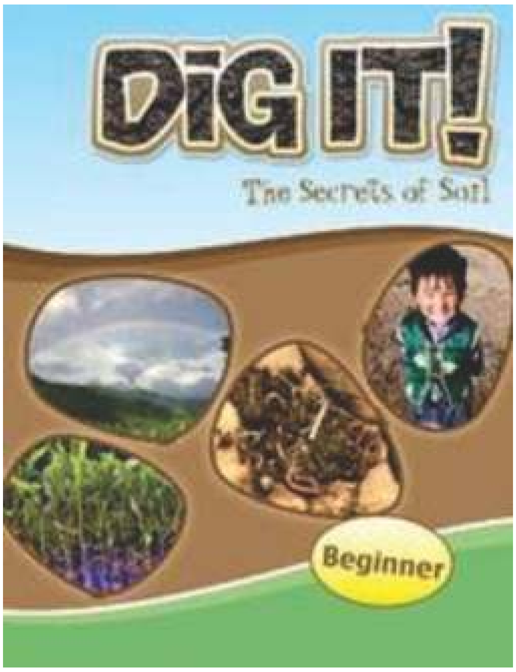
FAO launches series of educational materials on the role of healthy soils



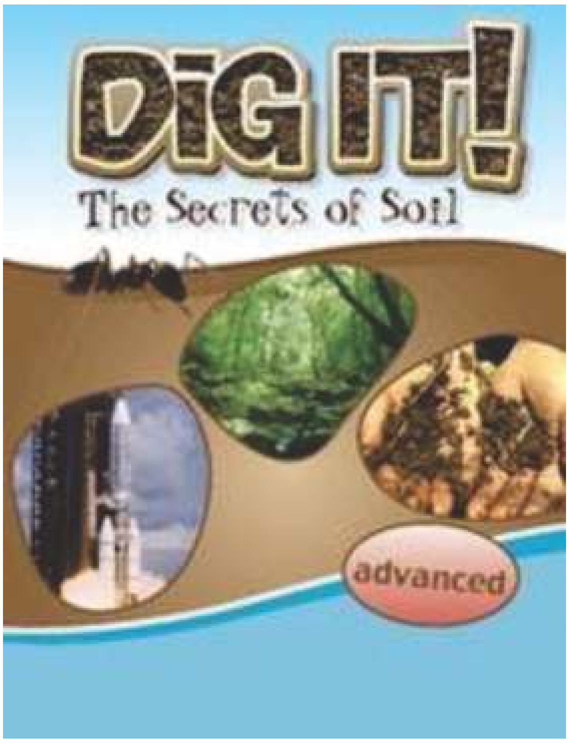
A new series of educational materials is teaching children the importance of healthy soils for our food, environment, livelihoods and well-being.

Educational Material

Learn more about soils through our educational booklets for children ages 5 to 14. An educator's guide is also available for teachers.



DIG IT! The Secrets of Soil
Beginner



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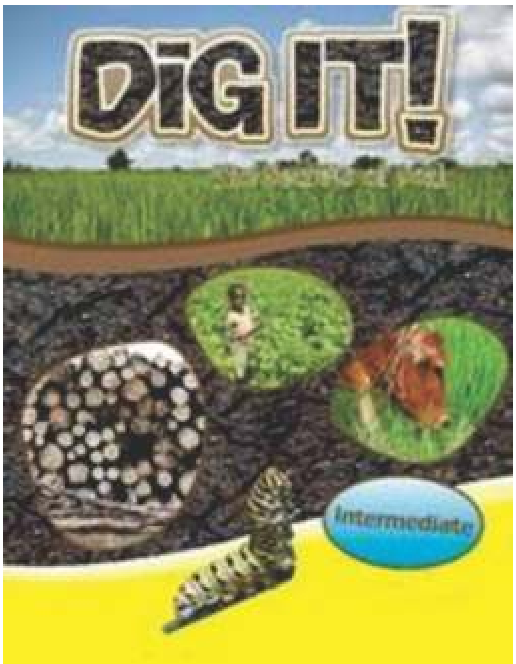

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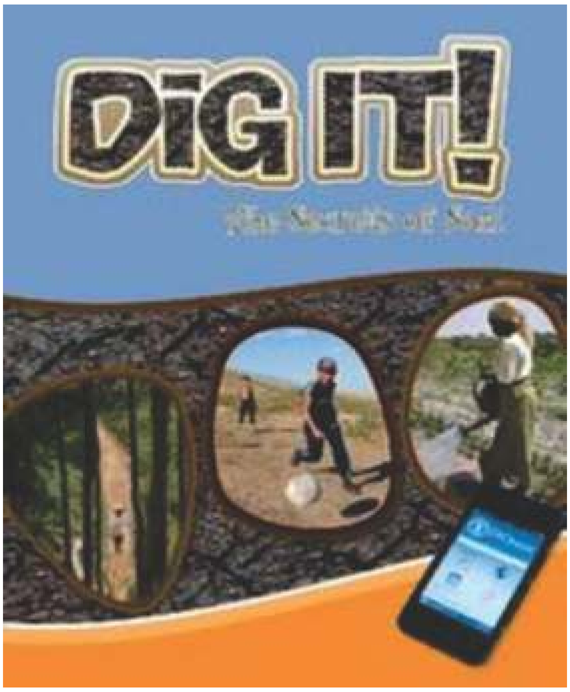

DIG IT! The Secrets of Soil
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THEME AND DEADLINE FOR NEXT ISSUE

The next edition of *Nature & Faune* journal will feature short articles linked to the theme of *"Sustainable management of forests and wildlife in Africa: enhancing values, benefits and services"*. This is consistent with the journal's mission to profiling the natural resource management and its contribution to sustaining livelihoods of people across Africa. This edition of *Nature & Faune* journal is one of the contributions of Food and Agriculture Organization of the United Nations to highlight the multi-facets of sustainable management of forestry and wildlife, and to fully capture their importance in sustaining the livelihood of millions of people and in contributing, in general, to sustainable development in the region.

As the world's forests continue to shrink as populations increase and forest land is converted to agriculture and other uses, the rate of net global deforestation has slowed down by more than 50 percent for the past 25 years. The good news is that increasing amount of forest areas have come under protection while more countries are improving forest management. This is often done through legislation and includes the measuring and monitoring of forest resources and a greater involvement of local communities in planning and in developing policies[1].

The year 2015 was critical and led to a new development era with the adoption of the 2030 Agenda for sustainable development. The post-2015 development agenda reaffirmed the importance of forest through its Goal 15: *"Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss"*. In September 2015, the XIV World Forestry Congress (WFC) produced the Durban Declaration[2]. The Congress offered a new vision for forests and forestry where (i) Forests are more than trees and are fundamental for food security and improved livelihoods. (ii) Integrated approaches to land use provide a way forward for improving policies and practices (iii) and Forests are an essential solution to climate change adaptation and mitigation.

Africa has achieved a momentum and reminded the Congress participants about the start of a journey towards "Africa 2063 Agenda"[3] and further urged Africans to translate the principles of "the Africa we want"[4] into concrete and actionable programmes in the forestry and natural resource management sectors. It further called for multisectorial integrated approaches of sustainable management of forest resources, technological innovations and strengthening in the forestry sector and for further investment and financing.

A new milestone has been set with the Paris Agreement, adopted during the Cop21 of the United Nations Framework Convention on Climate Change (UNFCCC) last December 2015. The recently concluded COP21 of the UNFCCC, further recognized the role of conservation, sustainable management of forests and enhancement of forest carbon stocks; as well as alternative policy approaches, such as joint mitigation and adaptation approaches for the integral and sustainable management of forests; while reaffirming the importance of non-carbon benefits associated with such approaches; encouraging the coordination of support from, inter alia, public and private, bilateral and multilateral sources.

To further measure and enhance the importance of forests, we need to improve our understanding of the people who live in and around forests, what kind of values, benefits and services do they get to sustain their livelihoods, and what kind of policies and regulations influence these interactions. The editorial board is therefore inviting authors to submit articles that address the broad contributions of forests, trees, wildlife and naturals resources in general on topics such as value addition of wood and non-wood forest products; forests and wildlife for social and economic development; forest and water resource management; forestry and climate change adaptation and mitigation; illegal hunting and trade; forest and wildlife policies; and forest and landscape restoration in Africa.

Deadline for submitting manuscripts for the next issue is 30 April 2016.

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[1] *http://www.fao.org/forest-resources-assessment/en/*

[2] *http://www.fao.org/about/meetings/world-forestry-congress/outcome/en/*

[3] *Africa 2063 Agenda is "A global strategy to optimize use of Africa's resources for the benefits of all Africans"*

[4] *The Africa We Want". It reflects a vision for Africa based on aspirations of African countries and their people, articulated in "Agenda 2063 – the Future We Want for Africa" as an "integrated, people-centered, prosperous Africa, at peace with itself". The Agenda 2063 also enhances the ideals of Pan-Africanism. Visit: http://agenda2063.au.int/*

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