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The impact of land management practices on soil quality and implications on smallholder productivity in Southern Highland Tanzania

Abstract

The impacts of land management on selected soil fertility properties and productivity of food crop were investigated in Rungwe volcanic area of southern Tanzania. The study involved fertility assessment of soil under: 1) forest reserve; 2) abandoned grassland covered with scattered trees; 3) 3 years fallow; and 4) land under continuous cropping. Land under forest was included as a bench mark soil with less influence from human activities. Soil parameters assessed per land use category were soil depths (cm), soil exchangeable bases and exchange properties ($cmol_c kg^{-1}$ soil). Communities' perceptions on soil fertility changes and productivity were also assessed through focus group discussions (FGD), whereby 25 village community members representing different age groups and gender were involved. Findings indicated that soil fertility varied according to land management, whereby a soil under forest reserve had deep A horizon and was rich in total exchangeable bases (11.80 $cmol_c$/kg soil) and with high in exchange property while that under continuous cultivation had low fertility with a total exchangeable bases of 3.28 $cmol_c$/kg soil. This depletion in soil fertility was described to lead into food insecurity due declining crop productivity over years. The main social economic activity in study area was identified to be agriculture, whereby both crops and livestock played a significant role. The three main wealth groups namely the: 1) rich; 2) middle; and 3) poor people reflects a very strong linkages among them in terms of livelihoods and resource management. To sustain productivity of volcanic soils, sustainable land management strategies need to be strengthened through research and training following an innovation approach involving key stakeholders.

Keywords: agriculture, forest reserve, Rungwe, soil profile, Lwifwa.
JEL Classification: Q15, Q18.

Introduction

The majority of people living in Sub-Saharan Africa (SSA) depend on natural resources in particular lands, which provide them with income and food through agricultural undertaking (Sha et al., 2008; Majule et al., 2009). Agriculture production, which also provides a significant contribution to most GDP of Africa reported to be 21% on average but ranging between 10% and 70% per country is challenged by several factors including climate change, variability and declining soil fertility (Tabo et al., 2007). Agriculture development in this region over the past decades has gone through a number of historical stages in terms of policy, research and training, infrastructural development as well as technological development with the aim of maximizing production in a sustainable manner. Agriculture development entails exploitation of natural resources in particular clearing of forest with the purpose of maximizing productivity in order to feed the ever increasing human population in the region (Kangalawe et al., 2005; Muganyizi, 2009; Maitima et al., 2009). For example, it is estimated that the production of food crops in Eastern and South Africa is 1.7 t/ha on average, which is nearly half of the average global production estimated to be 4.0 t/ha. Furthermore, about 200 million people in Africa are chronically hungry and 340 million people, which are nearly 50% of the total population live below $1 per day indicating high poverty level (Tabo et al., 2007). Agriculture production is challenged by several factors including ranging from poor production technologies, poor or lack of appropriate institutional arrangements such as credit facilities (Majule and Shishira, 2008), macro policy changes imposed externally such as structural adjustment and removal of subsidies on agricultural input. The most important issue is that if agriculture development activities are conducted in an unplanned way have resulted in a serious land degradation, in particular declining soil fertility of potential and productive volcanic soils leading into food and income insecurity (Majule et al., 2002; Majule et al., 2009; Maitima et al., 2009). Land degradation means a reduction or loss in arid and dry sub-humid areas of biological or economic productivity or complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest and woodland, resulting from land uses or from a process or combination of processes. These processes include those arising from human activities and habitation patterns such as soil erosion caused by wind or water, deterioration of the physical, chemical and biological properties of soils as well as loss of natural vegetation. A number of studies have been conducted to assess the various kinds of land degradation in East Africa (Dejene et al., 1997; Boesen et al., 1999; Kangalawe et al., 2005; Maitima et al., 2009).

This study focused in Mbeya region being among potential areas in Tanzania for producing different food crops including cereals, in particular, maize, wheat and relish crops such as beans (Gwambene, 2007). The conditions and productivity potential of the region is comparable to that of Kilimanjaro region also in Tanzania which have been extensively studied by Maitima et al. (2009). The area is endowed with a number of natural resources such as natural forests, fresh water from a series of crater lakes and rivers as well as fertile volcanic soils suitable for growing different crops and livestock keeping (Yannick et al., 2006; Laurent et al., 2007). Over decades, there have been a number of pressures on natural resources due to increased human demand associated with development and increasing human population leading to continuous cultivation of land and intensified agriculture on densely populated land (Muganyizi, 2009). These have lead into changes in farming practices resulting into land degradation likewise in other similar areas of Tanzania in East Africa resulting into reduction in crop productivity per unit land (O'Kting'ati and Kessy, 1991; Mary, 2005; Maitima et al., 2009; Majule et al., 2009). In response to declining soil fertility, a number of studies on how land productivity can be improved have been reported (Majule and Shishira, 2008).

It has been established that the productivity of different soils occurring in a wide range of ecological systems depended on how different soils are managed (Majule et al., 2009). Such kind of research allows for a scientific community to share knowledge on management aspects and hence up-scaling promising practices. For example, continuous cultivation of agricultural crops such as maize and tobacco, without the additions of fertilizer into the soil in many cases, have led to depletion of soil nutrients leading to declining crop productivity in many parts of SSA (Rowell, 1994; Majule et al., 2010). However, there might be different management options by indigenous people to address the problem. The objective of the study was to investigate soil degradation in the slopes of Mount Rungwe associated with different management and also to establish its implications on crop productivity and community livelihoods.

1. Research methodology

1.1. Description of the study area. The study was conducted in Rungwe District of Mbeya Region, which is located between latitudes 8°30' and 9°30' south and longitudes 33° and 34° east southwest Tanzania (Figure 1). The region is among the four major ones in producing and supplying different food crops within the country. The district has three agro-ecological zones, that is, highland (2,200 m.a.s.l), midland (1,200 m.a.s.l) and lowland (800 m.a.s.l) potential in producing different food and cash crops ranging form Irish potatoes, bean, wheat and maize (highland), banana, bean (midland) cocoa and rice (lowland).

The climate in Rungwe District is generally tropical, with marked seasonal and altitudinal temperature variations and sharply defined dry and wet season. The rains normally start in October and go through to May, followed by a dry and cold spell between June and September. Temperature averages range between 16^{o}C in the highlands and 25^{o}C in the lowland areas.

Soils in the upper and mid altitudes are mainly volcanic in nature and are covered with thick layers of volcanic and alkali basalt. The lower altitude consists of limestone lacustrine rocks (Muganyizi, 2009). In arable areas soils are most commonly of moderate fertility with coarse and of medium texture varying from sandy loams, alluvial soils to cracking clays.

The study covered Rungwe Forest Reserve (high land zone) and this was considered to be an area with undisturbed soil, Rungwe (midland zone) and Lwifwa villages (lowland zone) where different uses of land are found (Figure 1).

1.2. Data capturing and analysis. *1.2.1. Soil fertility characterization.* A transect was based on altitude and associated social economic activities starting from the mid slopes of the Rungwe Mountain at an altitude of 2,200 m.a.s.l to the lower part at an altitude of 1,200 m.a.s.l. Along a transect, a total of 4 soil profiles namely RFR P1, RTGr P2, RLF P3 and RCC P4 representing soils under: 1) Rungwe forest reserve; 2) Rungwe trees with grasses; 3) Rungwe land under fallow; 4) Rungwe under continuous cultivation for 100+ years were sampled. In Figure 1 these are indicated by Δ1, 2Δ, 3 Δ and 4Δ respectively.

The depths of A and B horizons were first measured before soil sampling for selected chemical properties analysis. Selected chemical properties analyzed using standard analytical procedure methods described by Rowell (1994) and adopted by Sakala (1998) and Majule (1999) were exchangeable bases (calcium, magnesium, potassium and sodium). The analysis was performed to establish soil nutrients qualities in order to explain reasons for soil productivity levels. On the other hand, measuring soil depth was intended to explain soil degradation due to soil erosion (Yanda, 1997; Majule, 2004).

1.2.2. Linking scientific evidence and community based knowledge on land use. The majority of village communities found in Rungwe District are widely distributed in the lower parts of Rungwe Mountain, where different social economic activities are undertaken.

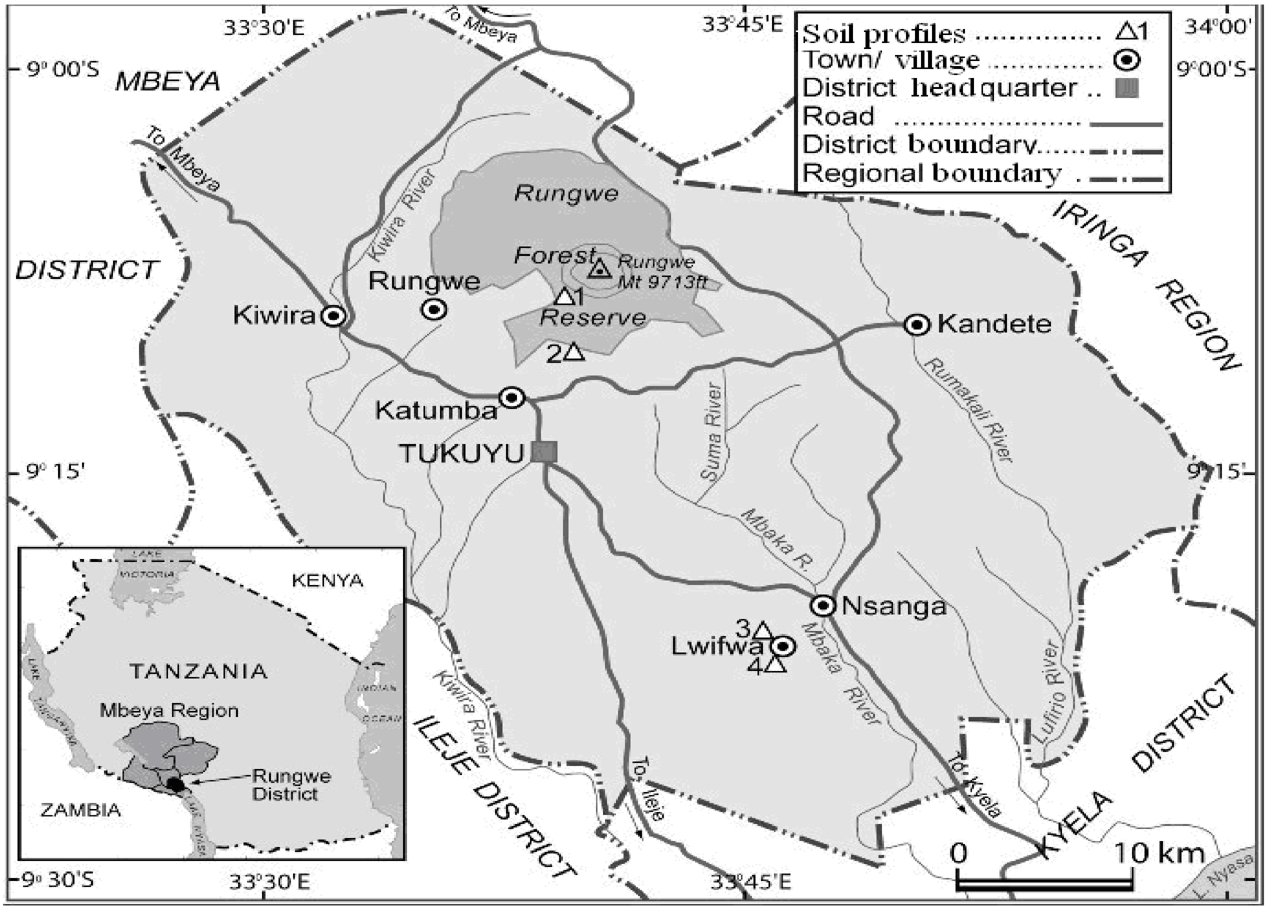

Fig. 1. Location of the study area and soil profile sites in Rungwe District

This distribution determines different cropping patterns and soil management practices and hence livelihood systems. In order to get an understanding on different factors that have contributed to changes on soil properties and productivity, patterns of land resource uses in the area and relationships among different social groups in creating wealth, a focus group discussion was used in data collection (Yanda et al., 2006; Majule and Shishira, 2008; Lema and Majule, 2009; Muganyizi, 2009). In this case, a group consisting of 25 key representatives of village members selected on the basis of age and gender were involved in the discussion. The group was made up of elder men and women (41-80 years old), village leaders and young generation of between 18 and 40 years old. This focus discussion was conducted at Lwifwa village during 4 hours. In this case a checklist with major questions for discussion was used. A similar approach was used by Gwambene (2007) and Muganyizi (2009) under similar conditions. For quantification of results given on a specific answer, a proportional pilling approach was used (Kangalawe et al., 2005). Under this approach 3 out of 25 participants within the focus group were given a total of 10 beans seeds each and were then requested to place them separately to on a flip chart, where an appropriate answer was indicated. For example, when do you think soil productivity was very high? (a period before independence, 20 years after independence or this period). If more seeds out of 10 are allocated in a place written before independence this means that period land was more productive. This was done by all 3 members selected and the number of seeds placed to specific answer were counted and converted into percentages out of 30. Once the groups agreed them a discussion followed to probe on reasons for giving such an answer and to explore on what happens to other historical period. In this case, the higher percentages indicated common and relevant answers. For describing patterns over time, three historical periods in Tanzania were used namely: 1) the pre-independence period (1961); 2) the post-independence period before villagilization (1961-1974); and 3) the post villagilization period (1975 to date). Villagilization in this case was a Tanzania human resettlement policy, which was implemented starting from 1975 by bringing people into small communal villages with a purpose of rendering social services close to them.

2. Results and discussion

2.1. Main socio-economic wealth groups in the study area. Three main social groups were identified in the study area based on ownership of different assets, size of land resource owns, the number and types of livestock, food and income securities and labour management (Table 1). Rich people locally known as *Unkambi* (in Nyakyusa) constitutes nearly 10% of the total number of households in the village and it is comparable to the same category in Iramba, Singida Region of Tanzania reported to be 9% (Kangalawe et al., 2005). This group is well respected in the village because it owns more assets and land and also it has powers to employ others especially during critical food shortage in the village (Gwambene, 2007; Lema and Majule, 2008).

Table 1. Characteristics of the three major social economic groups at Lwifwa village

Group	Major social characteristics
Unkabi (the rich) (10%)	Owns between 12-25 cattle; owns between 10-12 goats; has extra food to cover one season; owns more that 3 acres of land; owns land in there major land units; cultivates cash crops like cocoa, coffee and banana; tends to hire labor and is capable of inviting and feeding guests; can save between US 600 and 1000 per year.
Nkabi panandi (the middle class) (20%)	Owns between 5-7 cattle; owns between 3-6 goats; has enough food to cover one season; owns between 2 and 3 acres of land; owns land in middle and upper slopes; cultivates cash crops like cocoa, coffee and banana; sometimes tends to hire labor; occasionally invites guests; saves between USD 100 and less than USD 600 per year.
Undondo (the poor class) (70%)	Owns between 0-4 cattle; owns between 0 and 2 goats; has food shortage (4 months a year); owns land in upper parts or crests owns between 0 and 0.5 acres of land; cultivates banana, cassava, beans; tends to sell labor; can serve less than USD 100 per year.

The second group of people in terms of wealth is the middle class, which are approximately 20%. This group is locally known as *Nkabi Panandi* (in Nyakyusa). Although, the group does not have enough savings in terms of cash, it is very active in terms of investment into both livestock and crop production aiming to be rich. They have modern productive means and were reported to be very active in learning from the rich people. The majority of the communities in the village fall under the poor category *Undondo*, constituting nearly 70% of the total number of village households. The majority has limited access to land and tends to sell their labor to the rich people and some to the middle class. In Tanzania and other communities in rural areas of African countries such kind of relationship is very common (Majule et al., 2008; Kalisa et al., 2010). In this case, poverty in rural villages is likely to continue unless such inter-dependences are broken. This can only be achieved by building the capacity of the majority poor in terms of capital, training and land accessibility by changing tenure systems.

2.2. Land uses and its distribution. The study showed that at village level, especially in Lwifwa, major land use types in the village are: 1) human settlements; 2) agriculture; 3) livestock grazing; 4) burial sites; 5) forest land; and 6) others including wetlands and ritual sites (Table 2). The terrain in Rungwe District including Lwifwa village is characterized by undulating landforms and this allows for redistribution of land uses and livelihood activities. In this case based on the wealth of an individual within a village particularly, those who are rich tend to own land in all of the three land sub units, while the poor access land only in the upper parts (Table 1). This land ownership system favours the rich to own fertile soils while the poor manage poor soils and this result into poor crop productivity to the majority FGD revealed that a majority of communities settle in upper crests or upper slopes and a few of them in mid-slopes to allow farming activities to take place in moderately fertile land. Valley bottoms and foots slopes are also mainly for farming activities and are potential for dry season production of maize, bean and vegetables like wise in the neighboring Region of Iringa (Majule and Mwalyosi, 2005). The same is true for other valley bottoms in east and southern parts of Africa (Majule, 2008; Maitima et al., 2009).

Table 2. Distribution and use of land in the study area based on % of scores

Major landuse types identified	Major land sub units		
	Crests and mid slopes	Mid and foot slopes	Lower parts and valley bottoms
Human settlements	63	37	0
Agricultural land	20	63	17
Grazing land	53	37	10
Burial sites	83	0	17
Forest land	83	0	17
Other land uses	67	3	30

Agricultural activities (Table 2), including the cultivation of food and cash crops such as tea, banana, maize and irish potatoes is concentrated in mid and foot-slopes while cultivation of other crops such as rice and vegetable is common in foot slopes and valley bottoms. This cropping patterns is comparable that of slopes of Mount Kilimanjaro and Kenya in East Africa and have been reported to be very potential in supporting community livelihoods in such areas (Majule et al., 2009; Maitima et al., 2009). Grazing lands are located near homesteads, where patches of grass land are found. Lands for grazing are small in size but can support improved livestock keeping, which uses exotic grass species such as *Guatemala*, planted by farmers comparable to that of mid slopes of Mount Kilimanjaro in Tanzania (Mambo, 2005). Forests and burial sites are normally common in the upper parts of land units at village scales. In general, this land use categorization is very common in most villages in the Rungwe area. However, there has been pressure on landuses due to population increases, conversion of land into social infrastructure, climate change impacts and other factors likewise in other parts of Africa (Tabo et al., 2007).

2.3. Land productivity of different crops. It has been established that the main socio-economic activity in Rungwe District is agriculture. Agricultural production is for both subsistence and commercial purposes, with tea estates and coffee farms owned by rich middle people (Table 1). During the focus group discussion, different types of crops were listed to be grown in the study area prior to the independence period to date. The analysis presented in Table 3 clearly shows that there has been a well defined pattern in terms of the type of crops grown in the area and also productivity levels due to different factors. This pattern is not surprising because it has also been documented by other researchers in different agro- ecologic zones of Tanzania.

Table 3. Historical trend on the production of different crops in Rungwe District based on % of scores

Major food and cash crops	Historical periods		
	Pre-independence	Post independence before villagilization	Post villagilization
Banana	60	17	23
Maize	43	37	20
Cocoa	16	27	57
Cassava	23	27	50
Beans	23	60	17
Coffee	17	63	20
Groundnut	70	20	10

Based on communities' perceptions, banana production (Table 3) during the pre-independence period was reported to be very high because at that period rainfall patterns were normal and well distributed and soils were very fertile. Rainfall patterns during this period as reported by communities being high and well distributed correspond with rainfall trends analysis reported by Gwambene (2007) and Majule (2008). On the other hand, during that period there were very few plant diseases and pests that affected crops and livestock. During and post-independence, the production of banana is reported to decline progressively probably due to changes on policies on marketing and initial transformation by the goverment to small Ujamaa villages, which involved human resettlement. The implications of the human resettlement program on crop productivity have also been documented by Kangalawe et al. (2005) and Maitima et al. (2009). The major issue is that when a community is moved to a new area, it takes sometime for them to settle and open up new plantations. For the banana crop, there is a slight recovery in production after villagilization, suggesting that the settled community and other infrastructure such as marketing and transport were in place after villagilization period (see, for example, Mbonile et al., 2003). The productivity of other crops (Table 3) also declined due to the following reasons: 1) increases in pests and diseases, which was also linked to climate change in particular increase in temperature due to global warming; 2) declining soil fertility; 3) instability of crop prices such as coffee; 4) removal of subsidies on agricultural inputs; and 5) expansion of cocoa production on the expense of other crops. Reasons given for declining crop production in the study area are not surprising because they have also been reported to affect production in other parts of Africa (Tabo et al., 2007). Cassava production in the study area was reported to be a new crop and is becoming more common in the village (Table 3) due to declining fertility and increasing drought. These observations are in consistent with findings reported for mid slopes of Mount Kilimanjaro in Tanzania (Majule, 2004; Maitima et al., 2009).

2.4. Soil fertility management practices over decades. Table 4 presents a snapshot of how communities perceive the fertility of soils and production over time. In general, over time and due to changes in land use/cover types, there has been a decline in soil fertility. The Table indicates that during colonial period use of contours and terraces to conserve soil and water were common practices due to the strength of land management and by laws existed by that then. With time people abandoned such practices when such policies and strategies were abandoned. A similar case has also been report for Kilimanjaro and reasons given for such changes includes for example changes in policies and bylaws whereby people became reluctant to implement them (Majule et al., 2009). Currently, land management practice includes application artificial fertilizers, use of farmyard manure and agro forestry practices (Table 4) which is also stipulated within the national agriculture and Livestock policy for Tanzania.

Table 4. Approaches for soil and water conservation in the study village

Land unit in the village	Historical period		
	Pre-independence	Post-independence before villagilization	Post villagillization
Crests and mid slopes	Wide use of land terraces 3-5 years fallows Forest conservation Wide use of contour ridges	Few uses of land terraces 1-2 years fallow Conservation of woodlands	Increased use of artificial fertilizer Increased use of manure from animals 1 year fallow Mixed farming
Foot slopes and other land units	Incorporation of banana and grass and crop residues 3-4 years fallow Conservation of woodlands	Land fallow for 2 years maximum Trees crop mixture (*Avacardo*, *Citrus Mangoes* and *cocoa*)	Increased use of artificial fertilizer Increased use of manure from animals 1 year fallow Mixed crop farming
Lower parts and valley bottoms	Ridges and ties to drain water Deep tillage using hand hoes Crop residues management 1 year fallow	Ridges and ties to drain water Deep tillage using hand hoes Crop residues management 1 year fallow	Continuous cultivation Application of fertilizers in vegetables and rice farms

2.4. Impacts of land use on soil properties across transect. Rungwe volcanic area of Tanzania is characterized by volcanic soils. There are different groups of Andosols, which have been subjected to different physical conditions associated with socio-economic and demographic factors. This Section presents results of biophysical properties of 4 soil profiles (Figure 1).

2.5.1. Impacts of land management on soil depth (cm). In Figure 2, soil depths of A and B horizons measured during soil description tend to vary across soil profiles described under different land use types. A soil profile under Rungwe forest has the thickest A soil horizon (40 cm) suggesting accumulation of soil organic matter from forest litter with less disturbance by human activities such as grazing and crop cultivation. On the other hand, such soil is not subject to soil erosion, which normally washes away the A horizon (Rowell, 1994). On the other hand, the B horizon of such soil is also deep, suggesting absence of soil erosion and a high level of soil development. In addition, RTGr P2, which represents a soil and abandoned tea estate has A horizon with less then 30 cm suggesting human disturbances that have contributed to soil erosion and degradation. Normally, when a soil is subjected to continuous cultivation for a long time, soil organic matter tends to decrease (Rowell, 1994; Majule, 1999; Yanda et al., 2006).

Soil depths of A and B horizons has been used to assesses soil physical degradation in particular soil erosion (Yanda, 1997). The A horizon of soil under three years fallow in Lwifwa and that under continuous cultivation over more than 100 years showed a marked decrease in soil depth of A horizons due to observed erosion indicating influence of human activities (Figure 2).

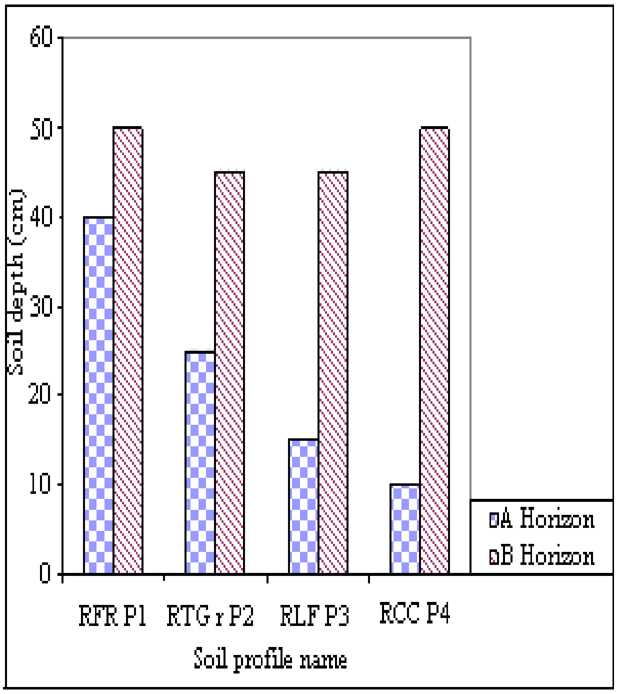

Fig. 2. Soil depths under different major land use types in Rungwe

2.5.2. Soil exchangeable bases. The concentration of major soil exchangeable bases, in particular calcium, magnesium and potassium in soils investigated is shown in Figure 3. Results indicate that concentrations of three major nutrients in the two horizons vary by land management, indicating impacts of land management practices on soil quality. Such variation is not surprising because it is in broad agreement with findings reported by Sakala (1998) and Majule (1999).

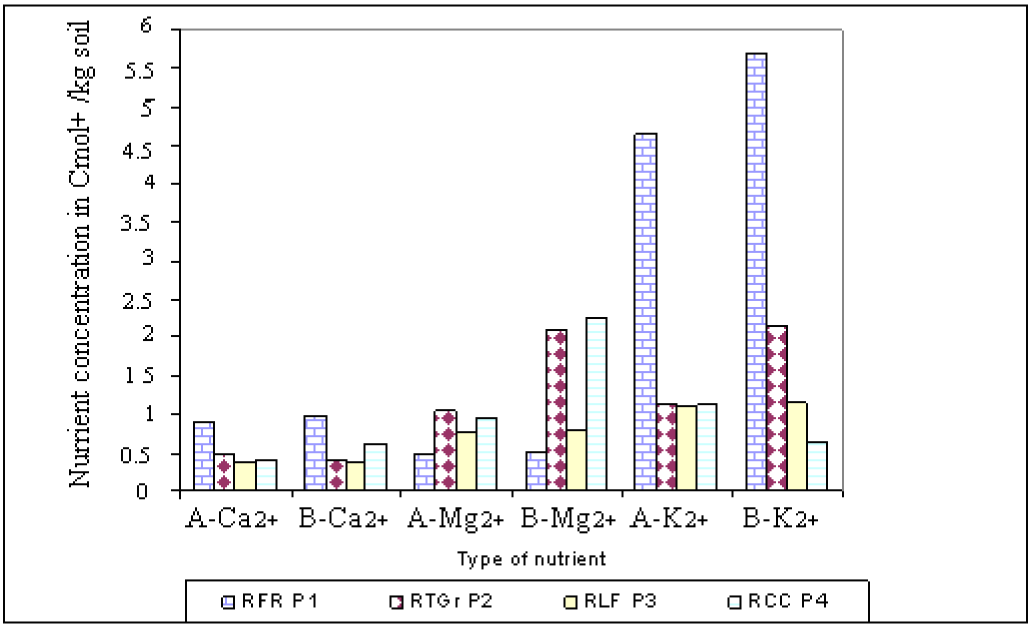

Fig. 3. Exchangeable basic element concentrations in soils

The concentration of exchangeable Ca^{2+} in soils was found to be within expected range for most tropical soils reported by Rowell (1994) and Majule (1999). Further, the concentration of exchangeable Ca^{2+} in both A and B horizons is well above a critical concentration of 0.02 $cmol_c$/kg soil according to Ritchey (1982). Although, this is well above a critical value for plant growth, there is clear evidence that a soil under forest reserve contains the highest concentration of exchangeable Ca^{2+} in A horizon with a slightly increase in B horizon, indicating both leaching and presence of ash material in the B horizon rich in calcium. Exchangeable Ca^{2+} levels in soils under continuous cultivation (RCC P4) and that under the soil 3 years fallow are generally low, indicating degradation of Ca^{2+} due to depletion of such nutrient elements. The result reported on the variation of Ca^{2+} concentrations due to management and in this case being lower in soils under continuous use is in consistent with results reported for similar soils on slopes of Mount Kilimanjaro (Maitima et al., 2009). This variation in Ca concretions in soils studies explains why encroachment of forest is increasing in study area and this is linked to higher productivity due to fertility of such soils. Forest conservation or promoting agroforestry practices could be a better option for nutrient management in such a potential area.

The concentration of other mineral elements, in particular exchangeable K^+ and Na^+, were found to be the highest in soils under forest reserve in A horizon. In B horizon also followed a similar pattern like that of Ca^{2+}, whereby increases were observed. Such pattern have also been reported by Majule et al. (1997) while investigating soil nutrient dynamics in soils under cashew trees in Tanzania. In general, the sum concentration of four major nutrients (Ca^{2+}, Mg^{2+}, K^+, Na^+) or effective cation exchange capacity (ECEC) in $cmol_c$/kg soil in A soil horizon were in the order RFR P1 (11.80) > RTGr P1 (3.43) > RCC P4 (3.28) > RLF P3 (3.17). In this case, soil under Rungwe forest reserve has a highest ECEC while soils under continuous cultivation and that under follow have low ECEC. The implication on crop production is that with decreasing levels of ECEC in soils productivity is also reduced. This is true with most soils in the tropic and what has been argued by many scientists is to develop management options that would add more input to soils which supplied such mineral concentrations. As reported by Rowell (1994) and also by Majule and Shishira (2008) major sources could be application of manure, addition of mineral fertilizers bearing for example calcium and also improve nutrient cycling through management of crop residues.

A scientific evaluation of selected indicators of chemical fertility of soils under different land use to a large extent explains what was reported by local communities during the FGD on the patterns and trends of soil fertility and productivity over time. Local communities' perception on decreasing soil fertility and eventually diminishing crop productivity levels reported by Gwambene (2007) and Muganyizi (2009) pinpoint declining natural fertility. Communities tend to respond either by abandoning a particular piece of land for growing crops into fallow or maximizing the use of mineral fertilizers and other options as indicated in Table 4.

In general, this study informs researchers and communities that volcanic soils are very sensitive to management if they are not used in a sustainable way. The soils in Rungwe were very productive during the pre-independence and post-independence periods, where pressure on land was low. Conversion of forest land into farm land as reported by Muganyizi (2009) has led to declining soil fertility as shown in this paper and also crop productivity reported by communities. This in general threatens community livelihoods and may further lead into poverty.

Conclusion

Lessons learnt from this study improve a scientific knowledge on how local communities can play a significant role towards addressing land management problems in a complex environment to sustain their livelihoods. Findings are comparable situations with similar conditions in East Africa and this provides an opportunity for sharing of information. There is clear evidence that the productivity of soils in Rungwe will continue to decline if strategic measures are not put in place to manage soil fertility in different soil units to support agricultural land. Application of mineral fertilizers and crop residues are among strategies to be promoted. However, there is a need to promote agro-forestry practices in the area because this will also address community needs for other resources reported to be diminishing. Based on findings a wider range of stakeholders needs to be involved in planning, promoting community based landuse plans and also a monitoring framework needs to be in place to ensure positive outcomes in terms of productivity.

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References

1. Boesen N.J., Kikula I.S. and Maganga F.P. (1999). "Sustainable Agriculture in Semi Arid Tanzania", University of Dar es Salaam, Tanzania, ISBN 99-60-311-8.
2. Dejene A., Shishira E.K., Yanda P.Z. and Johnsen F.P. (1997). "Land Degradation in Tanzania", Perception from the village, United States of America, ISSN: 0253-7494.
3. Gwambene B. (2007). Climate Change and Variability Adaptation Strategies and Implications on Land Resources in Rungwe District, Tanzania. M.Sc Dissertation, Institute of Resource Assessment, University of Dar es Salaam.
4. Kalisa D.P., Majule A.E. and Lyimo J. (2009). Role of Wetlands on Community Livelihoods Depending on Agriculture: the Case of Songwe River Basin, Southern Highland, Tanzania, The paper is in its final print to Africa Journal of Agricultural Research (forthcoming).
5. Kangalawe R.M., Majule A.E. and Shishira E.K. (2005). "An Analysis of Land Use Dynamics and Land Degradation Process In the Great Rift Valley, Central Tanzania: a Case of Iramba District", Book Published by OSSREA, ISBN 1-904855-62-8.
6. Laurent Bremond, Anne Alexandre, Mathew J Wooller, Christelle Hely, David Williamson, Peter A. Schafer, Amos Majule and Joel Guiot (2007). "Phytolith indices as proxies of grass subfamilies on east African tropical mountains", *Global and Planetary Change*, 61, pp. 209-224.
7. Lema M.A. and Majule A.E. (2009). "Impacts of climate change, variability and adaptation strategies on agriculture in semi arid areas of Tanzania", The Case of Manyoni District in Singida Regio, Tanzania, *African Journal of Environmental Science and Technology*, Vol. 3 (7), pp. 206-218.
8. Majule A.E. (1999). "The Effects of Organic Residues and Elemental Sulphur Additions to Soils of Southern Tanzania", pp. 11-38, Ph.D. Thesis, Reading University, UK.
9. Majule A.E., Clive C.P. and Nortcliff S. (1997). The Environmental Effect of Dusting Cashew (*Anarcadium occidentale* L) trees with sulphur in southern Tanzania, *Tropical Agriculture Journal*, Trinidad, 74, pp. 25-33.
10. Majule A.E., Shishira E.K. and Yanda P.Z. (2002). "Declining Soil Fertility: A Challenge for Sustainable Productivity of Land Under Cashew Farms, Southern Areas of Tanzania", *Journal of the Geographical Association of Tanzania*, Vol. 30, pp. 30-48.
11. Majule A.E., Shishira E.K. and Yanda P.Z. (2002). "Declining Soil Fertility:a Challenge for Sustainable Productivity of Land Under Cashew Farms, Southern Areas of Tanzania", *Journal of the Geographical Association of Tanzania*, Volume 30, pp. 30-48.
12. Majule A.E., Shishira E.K. and Yanda P.Z. (2004). "Soil Fertility Response to Application of Selected Organic Residues under sulphur dusting Environment, Southern Area of Tanzania", *Bunda Journal of Agriculture, Environmental Science and Technology*, Vol.3 (1), pp. 1-11.
13. Majule A.E. and Mwalyosi R.B.B. (2005). "Enhancing Agricultural Productivity through Sustainable Irrigation",

A case of Vinyungu Farming System in Selected Zones of Southern Highlan, Tanzania, A chapter in a Book Social and Environmental Impacts of Irrigation farming in Tanzania: Selected Cases, Edited by H.Sosovele, J. Boesen and F. Maganga. Dar es Salaam University Press, ISBN 9976-60-431-9.

14. Majule A.E. and Shishira E.K. (2008). "Participatory Development of Sustainable Soil Fertility Management Practices through Innovative Training, South eastern, Tanzania", *The ICFAI Journal of Environmental Economics*, Vol. 6, No. 3, pp. 7-23.
15. Majule A.E. (2008). "Climate Change and Variability: Impacts on Agriculture and Water Resource and Implications for livelihoods in Selected Basins. Towards Climate Change Adaptation", Inwent-Internationale Weiterbildung und Entwicklung gGmbH (publisher), ISBN: 978-3-939394-28-0.
16. Majule A.E., Mbonile M.J. and Campbell D.J. (2009). "Ecological Gradients as a Framework for Analysis of Land Use Change in East Africa", *African Journal of Ecology*, Volume 47, pp. 55-61.
17. Majule A.E., Liwenga E.T., Kangalawe R.M. and Yanda P.Z. (2009). Natural Resource Contribution to Community Livelihoods: Experience from Selected case Studies in Tanzania", Dar es Salaam University Press LTD: ISBN 978-9976-60-486-6.
18. Majule A.E., Yanda P.Z., Shishira E.K. and Mwakaje A.G. (2010). "Underlying Threats on Forest Reserves in Tabora Region, Western Tanzania", The Case of Igombe River and Simbo Forestry Reserves, *Journal Studia Universtatis Babes-Bolyai, series Geographia*, LV 1, 2010.
19. Mary J.M. (2005). Soil Nutrient Flow Dynamics in the Slopes of Mount Kilimanjaro, A case study of North Ward in Hai District, Tanzania. M.Sc Dissertation, Master of Arts (Geography and Environmental Management) of University of Dar es Salaam.
20. Mbonile M.J., Salome M. and Cosmas S. (2003). Landuse Change Patterns and Root causes of land use change in southern slopes of Mount Kilimanjaro, Tanzania. Land Use Change impacts and Dynamics (LUCID) Project Working Paper 25. International Livestock Research Institute, Nairobi, Kenya.
21. Muganyizi J. (2009). Land use Changes withn Agricultural Systems and their Implications on Food Security in Rungwe District, M.Sc. Dissertation, Institute of Resource Assessment, University of Dar es Salaam.
22. Ritchey K.D. (1982). "Calcium Deficiency in Clayey B Horizon of Savanna Oxisols", Soil Science, 133, pp. 378-382.
23. Rowell D.L. (1994). "Soil Sciences: Methods and Applications". Longman, London, England.
24. Shah M., Fischer G. and Velthuizen H. (2008). "Food Security and Sustainable Agriculture, the Challenges of Climate Change in Sub Sahara Africa United nations", New York.
25. Sakala M.G. (1998). The Effect of Incorporating Plant Residues on Soil Acidity in the Management of Tropical Soils. Ph.D Thesis, Reading University, UK, 220 pp.
26. Tabo R., Bationo A., Waswa B.S., Kandji S. and Kihara S. (2007). "Global Change and Food Systems", In Global Change Processes and Impacts in Africa, Otter L., Olago D.O. and Niang L. (Editors), East Africa Educational Publishers Ltd, ISBN 978-9966-25-526-5.
27. O'Kting'ati A. and Kessy J.F. (1991). "The Farming Systems on Mount Kilimanjaro", In the Conservation of Mount Kilimanjaro, William. D (ed.), Newmark, IUCN.
28. Yanda P.Z. (1997). Classification of Soil Degradation Intensity as a Basis for Soil and Water Conservation Strategy in Semi-Arid and Sub-Humid Areas: an Example from Mwisanga Catchment, Kondoa, Central Tanzania, *Journal of the Geological Society of Tanzania*, Vol. 1, 1997.
29. Yanda P.Z., Majule A.E., and Mwakaje A.G. (2006). "Implication of Farming Practices on the Environment, Food Security and Poverty Levels in Matengo Highlands, Mbinga District, Southern Tanzania", *The ICFAI Journal of Environmental Economics*, Vol. 4 (1), pp. 55-80.
30. Yannick G., David W., Laurent B., Olivier R., Vincens A., Guillaume B., Joel G., Simon B., Pierre-Etienne M. and Majule, A.E. (2006). "Solar and anthropogenic imprints on the Lake Masoko (southern Tanzania) during the last 500 years", J Paleolimnol, Springer DO1 10.1007/s10933-006-9033-6.