Tanzania Forest Conservation Group
Shirika la Kuhifadhi Misitu ya Asili Tanzania

Adding Value to the Arc: Forests and Livelihoods in the South Nguru Mountains (AVA) Project

TFCG Technical Paper 46

Climate Smart Agricultural Options for Small-scale Farmers in the South Nguru Mountain Landscape, Mvomero District, Morogoro

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EXECUTIVE SUMMARY

Background

The Tanzania Forest Conservation Group (TFCG) in collaboration with several national and local partners is working to improve conservation of biodiversity in the South Nguru Mountains Landscape while improving livelihoods of communities within the landscape. Improvement in farming practices, among others, has the potential to contribute to both improved conservation and poverty alleviation. However, agriculture is faced by two interrelated problems of declining soil fertility, and deforestation and forest degradation. As soil fertility continues to decline farmers are forced to increase agricultural productivity through clearing forests and woodlands to expand their farms. This contributes to global anthropogenic greenhouse gas (GHG) emissions, resulting in accelerated climate change manifested in global warming. At the same time, the resulting climate change is another foe that threatens agricultural production and food security. This situation creates a vicious cycle of poverty that must be broken.

Adoption of appropriate agricultural technologies such as climate smart agriculture have the potential to deliver the tetra- win situation of addressing poverty, food security and withstand the changing weather conditions while at the same time contributing to climate change mitigation. This should also address any market barriers that are likely to hinder adoption of improved farming practices.

This report presents an ex-ante evaluation of potential climate smart agricultural options based on biophysical and social-cultural realities of the landscape. It forms part of an overarching process to develop a site-specific agricultural strategy for the South Nguru Mountains Landscape. This report highlights on suitable crops/crop combinations and suitable management practices in different agro-ecological zones that are financially viable; analyses barriers related to market and value chain governance; and proposes feasible ways to overcome the identified limitations.

Methodology

Field activities were carried out between March and April 2015. Information/data was collected using the following approaches: (a) review of various documents (b) stakeholders' consultation workshop (c) biophysical study that handled land suitability assessment based on primary soil data and documented climatic characteristics (d) Socio-economic study carried out in representative villages to cover wealth ranking, focus group discussion, group interviews and household questionnaires. Analysis of biophysical data involved dividing the landscape into homogenous mapping units corresponding specific set of soils, topography, rainfall and temperature characteristics. This was followed by matching crops / crop combinations to mapping units was done based on predetermined requirements of different crops / crop combinations. Spatial distribution of different crops / crop combinations suitability across the landscape was presented. Analysis of socio-economic data involved summarising focus group discussions and group interviews into relevant themes. The data from the household questionnaires were coded and analyzed using the Statistical Package for Social Sciences (SPSS) to generate relevant descriptive and inferential statistics.

Results

Crops / crop combination suitability and financial analysis

Distribution of crops/ crop combinations suitability varied greatly within and between villages. The detailed spatial distribution is presented in the report. Financial analysis matched with crops/ crop combinations suitability with few exceptions. The general trend was as follows:

1) Maize: suitable in humid lowland and marginally suitable in highlands
2) Rice: suitable in humid lowland and valleys in dry lowland
3) Beans and cowpeas: suitable in dry lowland and marginally suitable in humid and sub-humid highlands
4) Banana: marginally suitable humid lowland, sub-humid and humid highlands
5) Mangoes and citrus: suitable in dry and humid lowland, humid and sub-humid highlands

6) Avocado: suitable humid lowland, sub-humid highlands and humid highlands
7) Cocoa: suitable humid foothills and marginally suitable humid lowland
8) Teak: suitable in humid lowland; marginally suitable in dry lowland, humid and sub-humid highlands
9) Cassava: Suitable in foot hills in humid highlands and marginally suitable in all other areas except valleys
10) Tomatoes: suitable in dry and humid lowland and marginally suitable in humid and sub-humid highlands
11) Sesame and sunflower: Suitable in dry and humid lowland; marginally suitable in humid and sub-humid foothills
12) *Grevillea robusta* and cardamom: highly suitable in valleys of dry lowland; suitable in foothills of humid lowland, sub-humid and humid highlands.

Agricultural price information system and market related barriers

Agricultural price information is currently disseminated through farmers-to-farmers and buyers-to-farmers. The former was prevalent in villages close to town centres whereas the latter was common in remote areas. The major market related barriers were poor road infrastructure, long distance to the market, poor cooperation among farmers and limited access to agricultural price information.

Conclusions

In most cases biophysical features and therefore suitability and profitability of different crops/ crop combinations vary greatly within and between village and most villages have multiple sets of suitable crops/ crop combinations. Therefore, the resultant spatial distribution of the potential crops/crop combinations does not necessarily coincide with village boundaries.

Although, continuous cropping without any inputs is not only environmentally destructive but also financially unattractive, the poorest have maintained it due to their low opportunity cost. Application of inorganic fertilizers is always more financially attractive than agroforestry. Combining inorganic fertilizers and agroforestry is more productive and profitable, and has an added advantage of minimizing negative fertilizer impacts on the environment. Despite favourable socio-cultural factors such as profitability and attitude to environmental conservation, adoption of most of climate smart agricultural options is likely to be limited by high investments cost.

Cultivation of cocoyam and cardamom are associated with deforestation and forest degradation in the landscape, as farmers search for shade microclimate and good soils with high organic matter needed for better growth of the crops. Carefully designed agroforestry system can provide soils and micro-climate condition necessary for production of cocoyam and cardamom.

Inadequate access to agricultural produce price information is a serious constraint to bargaining power. Buyers tend to take advantage of farmers ignorance to dictate farm-gate prices. This together with poor roads, long distances to market places and inadequate cooperation among farmers present the key market barriers for the farmers in the landscape.

Recommendations

1) Appropriate soil and water conservation measures such as contour farming, alley cropping are recommended in order to enhance suitability of most steep slopes for crop production. Previous experience from Uluguru Mountains can provide valuable lessons to guide dissemination of these technologies.
2) Promotion of improved chicken production is recommended as an appropriate entry point to help the poor and poorest move out of poverty; and gain access to investments capital

needed for climate smart agricultural options. Village savings and loans (VSL) is proposed as an appropriate credit scheme to enhance adoption of climate smart agricultural options and help farmers to organise to forward their voices.

3) It is recommended that *Grevillea robusta* and teak trees be grown in either monoculture woodlots for farmers with ample land holdings (10 acres or more) or mixed with crops for farmers with medium sized farms (3 to 5 acres). For farmers who have small land holdings (less than 3 acres), trees should be planted along farm boundaries.

4) Appropriate agroforestry systems that integrate coppicing trees with annual crops for the first five years can create suitable soils and microclimate conditions for production of cocoyam and cardamom from the sixth up to tenth years of the system before trees are cut to start the cycle afresh with coppice regeneration.

5) Establishments of mobile phone based market information system can help the farmers to access relevant agricultural produce price information to enhance their bargaining powers. However, this will require a well though investments and sustainability options. Encouraging farmers to use Eastern Arc Mountains Conservation Endowment Fund (EAMCEF) can help to resolve the most of the funding issues for community based initiatives.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PLATE

LIST OF ANNEXES

1. INTRODUCTION

1.1. Background

With funding from the European Union, the Tanzania Forest Conservation Group (TFCG) in collaboration with several national and local partners is implementing "Adding Value to the Arc: Forests and Livelihoods in the South Nguru Mountains" project since January 2013. The life span of the project is five years, and it is being implemented in 34 villages adjacent to the South Nguru Mountains in Mvomero District, Morogoro region. The goal of the project is to alleviate poverty and improve economic resilience among marginalised rural communities in Mvomero District, Tanzania.

To achieve this goal, the project intends to develop and implement conservation-compatible enterprise opportunities. Such opportunities give primacy to interventions that can stimulate innovation and change in agriculture, which is the hub of wealth creation and diversification for many African countries (Ellis and Allison, 2004). Agriculture in many African countries is faced by two interrelated problems which are declining soil fertility, and deforestation and forest degradation. As soil fertility continues to decline farmers are forced to increase agricultural productivity through clearing forests and woodlands to expand their farms. Consequently, deforestation due to agricultural activities contributes 12 to 20% of global anthropogenic greenhouse gas (GHG) emissions, resulting in accelerated climate change manifested in global warming (Harris et al., 2012). At the same time, the resulting climate change is another foe that threatens agricultural yield and food security due to unpredictable and increased extreme weather conditions (McIntyre et al., 2009). This suggests the need for adoption of agricultural technologies that are capable of delivering the tetra- win situation of addressing poverty, food security and withstand the changing weather conditions while at the same time contributing to climate change mitigation.

Conversely, access to technology, infrastructure and the way people interact with institutions, such as markets and overall value change governance, influence adaptive capacity of many communities in Africa. Unfair market relations reduce the profit margin going to farmers, which in turn reduces their capacity to adapt to the impact of a changing climate. For example fertilizer prices have continued to rise and farmers cannot afford to apply optimal doses. To the contrary, profit margins to farmers have been dwindling and failing to meet the essential production costs, which reduces agriculture productivity and their adaptive capacity. Therefore, successful adaptation measures for agriculture sectors should integrate mitigation measures to address negative impacts to the environment; promote access to appropriate production and storage technologies; and improve market governance.

Crop adaptation to climate change requires transformation of existing farming systems through rigorous multifaceted scientific and technological approaches. This entails three phases, namely, basic on-station research, on-farm adaptive research for evaluation/testing to enhance initial selection of adaptable technologies and the dissemination phase (Ngambeki and UNECA, 2003). Studies show that neither agricultural research nor on-farm trials have been done intensively in most African countries, and Tanzania is among the countries lagging behind. However, a few on-station studies from different African countries have demonstrated sets of successful farming technologies across different environmental gradients in the sub-Saharan Africa (e.g. Sleshi et al., 2008; Bationo et al., 2008). However, the potential from these studies remains largely unexploited in most sub-Saharan Africa (Giller *et al*., 2009). The slow pace in dissemination of the tested appropriate agricultural technologies can be attributed to lack of appropriate methodologies and tools (Amede, 2004); and inadequate approaches to fit with diverse physical and social environments at farm and landscape levels (Jones, 2002; Ojiem *et al*., 2006; Giller *et al*., 2011).

It is against this background that the Adding Value to the Arc project, prior to embarking on the development of a specific agriculture strategy for the South Nguru Landscape, solicited technical support from a team of consultants to identify climate smart agricultural options that will mitigate negative impacts to environment and optimize productivity while taking into account the dynamic biological, physical and social-cultural aspects within the landscape. This is expected to ensure the tetra- win situation of addressing poverty, food security and withstand the changing weather conditions while at the same time contributing to climate change mitigation. This technical report presents an ex-ante evaluation of the different potential climate smart agricultural options within biophysical and socio-economic realms of the South Nguru Mountains Landscape. The options have specific focus on suitable crops/crop combinations and suitable management practices in different agro-ecological zones that are financially viable; and analyse barriers related to market and value chain governance and establish feasible ways to overcome them.

1.2. Objective of the consultancy

Develop a set of climate smart agricultural options which are compatible with the biophysical and socio-economic realities with a specific focus on suitable crops/crop combinations and suitable management practices that are financially viable, and analyse barriers related to market and value chain governance and establish feasible ways to overcome them in the South Nguru Mountains Landscape. More details in the terms of reference presented in Annex 1. Specific objectives of the consultancy are:

- To provide accurate, well-referenced data on the potential of different crops/crop combinations to contribute to improved livelihoods and enhanced climate change resilience for small-scale farmers living in the South Nguru landscape.
- To provide a clearly articulated comparative analysis of the relative profitability of different crops to small-scale farmers living in different zones of the South Nguru landscape.
- To review agricultural product price information systems potentially available to small-scale farmers in Mvomero District; and other value addition initiatives or innovations.
- To identify market-related barriers facing small-scale farmers in the South Nguru landscape and to make recommendations on interventions that the project could support in helping farmers to overcome those barriers.

2. LITERATURE REVIEW

2.1 Land capability assessment

Land is a valuable resource, which its best use depends on its suitability for that particular use and/or appropriate and economically feasible management to improve the suitability. The assessment of land capability will help to improve productivity of agricultural land given limited land availability due to increased population growth and demand for other uses while conserving the environment (Ziadat and Sultan, 2011). Attributes of land that determines capability of land for agricultural use includes, climate, soil, and terrain, which their characteristics are used to classify the area in terms of land suitability classes (FAO, 1976). In order to establish the suitability classes, first the optimal environmental requirement for particular use have to be established, and secondly, the actual land conditions where the particular use is going to be implemented. Then, the comparison of the optimal and actual conditions i.e matching is done, where actual land factors that meet or do not meet the optimal requirement for particular use/crop are identified. The factors that do not meet the optimal requirements are termed as limiting factors and are the ones that plays significant role in deciding the suitability class as by Liebig law of minimum (Roossiter and van Wambeke, 1989; Sys et al., 1991). Accurate assessment of limiting factors of these attributes is critical for land suitability assessment (Zaidat and Sultan, 2011). The land capability assessment for agriculture takes into account the crop requirement in terms of growth conditions (nutrient availability, climate requirement) and the area's physical characteristics. Thus establishment of both accurate crop optimal requirement and identification of actual physical conditions limiting a particular crop is required for improved productivity and sustainability of agriculture.

Assessment of land capability has been used in many research and projects with varied procedures. Conventional land capability assessment employs detailed soil survey to determine the physical characteristics of land and soil, with or without socio-economic assessment and match physical and or economic factors with a particular land use requirements. Msanya et al. (2001) adopted conventional soil survey to determine land suitability for maize, rice, sesame, and citrus in the eastern part of Morogoro rural, and reported that citrus is most suitable crop for 90% of the area, while maize is suitable for 57% of the land despite of being a popular crop. The most crop growth limiting land characteristics in the eastern part of Morogoro rural is poor soil fertility and severe soil erosion (Msanya et al., 2001).Thus, under appropriate soil fertility management and erosion control measures, the productivity of maize can be increased and sustained and thereby improving land suitability for maize in eastern part of Morogoro rural. Other approaches integrate detailed soil survey and farmers indigenous knowledge about their environment and modify the land suitability classes. Zaidat and Sultan (2011) integrated a detailed soil survey with indigenous knowledge in land suitability assessment in some parts of Jordan and reported that when conventional land suitability assessment was done only 1% of land was highly suitable for drip-irrigated vegetables and moderately to marginally suitable for open range, improved range, rain fed barley and irrigated trees. However, when integrating the indigenous knowledge and conventional soil survey, 18% of the land was highly suitable for drip-irrigated vegetables and 25% for irrigated vegetable. These results showed that, integrating indigenous knowledge provide an option to include management practices that improve land suitability for particular use as in the existing or current use. Therefore, land suitability assessment that identifies the limiting factors and appropriate management are more practical for implementation projects that aim at improving agricultural productivity. The current trend of land suitability assessment aims at achieving efficient land resource utilization given finite fertile land and competitive uses of the land (Smyth and Dumanski, 1993).

2.2 Soil characterization and soil management practices

2.2.1 Arable farming systems

Soil resource is one of the most important natural components of the land, which to a great extent determines the suitability of the land for particular use. The soil is a function of geology of the area, climate, topography, vegetation and time. Thus, soils differ in physical and chemical properties depending on the influence of soil forming factors. Thus, when characterizing the soils to determine its suitability for a particular use and management practices to improve and sustain a particular use, consideration of climate, landscape and natural vegetation should be considered. The suitability of the soil for crops and trees production and hence the management practices is determined by soil qualities that affect soil fertility. These soil qualities includes soil chemical properties such as soil pH, soil salinity, organic matter content, nutrient content (TN, P, K, S, Zn, Cu, Fe, Mn). Soil pH, soil organic matter content and CEC determines the availability of plant nutrients in the soil for root absorption. Soil fertility quality of land has been reported as the most important constraint to improved agricultural production in many areas of Tanzania, especially in small holder farming system (Amuri, 2015; Massawe and Amuri, 2012; Mowo et al., 2006; Msanya et al., 2001). The soil physical characteristics include soil texture and soil moisture characteristics, which affect not only nutrient retention, but also water infiltration and root permeability.

The major problem facing the Tanzania farming system is lack of soil characteristics information, which is a major drawback to sustainable soil fertility management to enhance resilience of agriculture to climate change. Lack of soil information is due to limited access to soil testing services (Amuri et al., 2013), and also limited awareness of the importance of soil testing services among small scale farmers in Tanzania.

Appropriate soil management practices and technologies that address a particular soil characteristic that limit particular use is required if climate smart agriculture is to be achieved. Climate smart agriculture utilizes technologies and practices that improve and sustain productivity, enhance adaptation to climate change, and reduce greenhouse gas emissions while achieving food security and development goals at local and national scale (FAO, 2010).

Soil fertility management to meet climate smart agriculture should focus on site specific management requirements, based on the current soil nutrient status to avoid environmental degradation due to excess or deficiencies of nutrients. Sustainable soil fertility management must maintain or adjust soil pH to levels suitable for a particular crop, maintain and increase soil organic matter, in addition to ensuring all essential nutrients are at levels sufficient for crop growth and yield. In this regard, inorganic and organic sources of nutrients complement each other. Thus, integrating organic and inorganic fertilizers, and cropping systems that improve soil organic matter is important.

Soil and water conservation is an important soil management that controls erosion; and improves water infiltration and retention of moisture in the soil profile. Control of soil erosion is crucial especially in steep slope areas and undulating plains with large surface area for runoff accumulation. Preventing soil erosion helps to sustain productivity by maintain soil particles and nutrients, and soil organic matter. Evidence shows that lack of soil erosion control is the number one cause of drastic decline in land productivity and require a lot of inputs and time to bring the land to be productive again (Kimaro et al., 2008). Soil and water conservation technologies are well documented with great success where logically implemented. *In situ* rain water harvesting using tied-ridges, chololo pits or zai pits improved productivity in semi-arid areas of Dodoma, Tabora and West Africa (Mati, 2000; Gowing et al.l, 1999). Reducing the length of steep slopes (of about 35 to 55%) by terraces using fanyajuu (for slopes between 12 to 35%), where a trench is dug across the slope and the soil is thrown up the slope (Malisa, 2010). Other ways to reduce steep slopes includes use of grass strips across the slope or "*miraba*" squares by planting grasses around the plot in sloping land. These soil and water conservation techniques using terraces and grass strips are widely used in Lushoto (Msita et al. 2012). Similarly, agroforestry practices such as alley cropping, tree rows planted along the contour or simply across slope, reduce soil erosion and improve soil fertility (Narain et al., 1998; Wei et al., 2007). Most alley cropping studies were conducted in West Africa (Kang and Wilson, 1987) and Kenya (Muthiri et al., 2005). In Tanzania, alley cropping studies were located in lowlands (Lulandala and Hall, 1990; Chamshama et al., 1998), which limits their applicability. The major limitation associated with alley cropping, especially in dry areas, is possible competition for soil moisture between trees and crops grown in the alleys (Rao et al., 1998). However, manipulation of planting spacing and proper tree species selection can overcome this limitation (Muthuri et al., 2005).

In areas where rainfall is low and erratic, more effort to store water in the soil profile by increasing infiltration through breaking hard pan, conservation tillage (reduced soil disturbances) and reducing evaporation through mulching. Mkoga et al. (2010) reported greater yield due to improved moisture conservation under conservation tillage (4.4 t/ha) than in conventional tillage (3.6 t/ha) in semi-arid areas of Mkoji sub catchment of Ruaha Basin, Tanzania when the rainfall was < 700 mm. Enfos et al. (2013) reported 41% increase in yield under conservation tillage due to better moisture retention in the soil over the conventional tillage only when the rainfall was >500 mm, and a cumulative yield increase of 17% when including poor seasons with rainfall < 500 mm. Another study comparing the effect of runoff water diversion into trenches of fanyajuu, *in-situ* rainwater harvesting and reduced tillage revealed a yield increase up to 4.8 t/ha over 1 t/ha under the conventional tillage (hand hoe without soil and moisture conservation) in semi-arid areas of north-east Tanzania where rainfall is less than 600 mm (Makurira et al., 2011).

2.2.2 Production dynamics and greenhouse gases in irrigated rice farming systems

Rice is grown in continuous or intermittently flooded paddies that favour formation of methane (CH_4) and nitrous oxide (N_2O), which are the two important greenhouse gases (GHG) (Smith et al., 2008). Soil water management is one of the key components in flooded rice systems that influence productivity, water use efficiency and emissions of greenhouse gases, notably methane (CH_4) and nitrous oxide (N_2O). Studies have shown that the system of rice intensification (SRI) which uses low height/level (1 – 3 cm) of flooded water or alternate drying and flooding can attain the same or higher yields using low amounts of water. Also, both methane and nitrous oxide emissions are also reported to be reduced when SRI is used.

2.2.2.1 The system of rice intensification

System of Rice Intensification (SRI) refers to a set of rice field management practices adapted to farmers' local conditions that are applied with the aim to minimize external inputs while maintaining high rice yields.

The fundamental principles of the SRI include (Uphoff, 2003):

a) **Condition of rice seedlings at transplanting:** transplanting young seedlings at the age of less than 15 days and proper handling of seedlings to avoid desiccation and root deformation ensures greater potential for tiller and root growth
b) **Optimum planting density (25 cm x 25 cm to 35 cm x 35 cm)**: ensures production of healthy and fertile tillers
c) **Soil aeration:** intermittent irrigation with shallow flooding of 1 – 3 cm (rather than permanent flooding of 10 – 20 cm) especially during the vegetative growth period prior to panicle initiation ensures good aeration necessary for healthy growth of the rice plant.
d) **Weeding:** use of mechanical weeding rather than flooding or chemical weeding ensures batter care for soil microorganisms that maintain soil health
e) **Fertilization:** appropriate dosage and timing of application of inorganic and organic manures may ensure better soil nutrient use efficiencies and overall nutrient conservation.

Less CH_4 emission from intermittent irrigation in the SRI is attributed to relatively good soil aeration generated due to periodic drainage of water (Bronson et al., 1997). Drainage creates oxic condition in the soil sediments, which suppresses methanogenesis process leading to low CH_4 production (Singh et al., 2003).

The potential of SRI to simultaneously enhance production while reducing emission of the greenhouse gases has been demonstrated in more than 20 countries (Satyanarayana et al., 2007). Uphoff (2003) synthesized results from different SRI studies and found that average yield from SRI was 6.8 t ha^{-1} compared to 3.9 t ha^{-1} recorded from conventional rice production. Satyanarayana et al. (2007) reported yield gain in SRI of 20 – 50% and corresponding decrease in water uses across different countries.

2.3 Greenhouse gases emission from agricultural fields

2.3.1 The concept of Global Warming Potentials

Global warming potential (GWP) provides the common scale for comparing the relative effects of one source or sink of greenhouse gas against another. GWP places all fluxes in common terms, which enables direct evaluation of the relative cost of, for example, increased carbon storage due to crop or tree residue production (GWP mitigation) against increased N_2O from additional fertilizer application (GWP source).

According to IPCC (2001), GWP is measured in CO_2-equivalents. Conversions from other gases to CO_2-equivalents are based on the effect of a particular gas on the radiative forcing of the atmosphere relative to CO_2's effect. GWP is determined by the ability of a given greenhouse gas molecule to capture infrared radiation; its current concentration in the atmosphere, the concentration of other greenhouse gases; and its atmospheric lifetime. Ceteris paribus, a gas molecule with a greater atmospheric lifetime will have a higher GWP than one that cycles rapidly. The GWPs values for different gases are used to compare the relative greenhouse effect danger associated with specific greenhouse gas. GWP values allow policy makers to compare the impacts of trade-offs between simultaneous emissions and reductions of different gases such as CH_4 and N_2O that may occur in equilibrium in rice farming systems (Linquist et al., 2012).

Overall, only three greenhouse gases are affected by agriculture: CO_2, N_2O, and CH_4 (Robertson and Grace, 2004). Although CH_4 and especially N_2O are at much lower atmospheric concentrations than CO_2; their GWPs are much higher so small changes have a disproportionate effect on radiative forcing (Table 1).

Table 1: Global warming potentials of greenhouse gases in agriculture (IPCC, 2001 cited by Robertson and Grace, 2004)

Greenhouse gas	Atmospheric life time (years)	20-year GWP	100-year GWP	500-year GWP
Carbon dioxide	-	1	1	1
Methane (CH_4)	12	62	23	7
Nitrous oxide (N_2O)	114	275	296	156

For example, based on IPCC (2001) the GWP value for Methane (CH_4) over 100 years is 21 compared to 310 for Nitrous oxide (N_2O) over the same time horizon. Thus, considering N_2O that is long-lived relative to CH_4, the 100-year N_2O GWP (296 CO_2-equivalents) is not much different from its 20-year GWP (275 CO_2-equivalents). On the other hand, the GWP for methane (CH_4) falls off rapidly over this period, from 62 to 23 CO_2-equivalents. Likewise, relatively novel molecules with high infrared capture capacities will have higher GWPs. Sulfur hexafluoride (SF_6), for example, has a 100-year GWP that is 22 200 times that of CO_2 owing to its radiative properties, its novelty in the atmosphere, and an atmospheric lifetime of 3200 years. Similarly, over a 20-year time horizon, the GWP of CH_4 is 62 while that of nitrous oxide (N_2O) is 275. The implication is that a molecule of contemporary N_2O released to the atmosphere will have 275 times the radiative impact of a molecule of CO_2 released at the same time, over a 20-year time horizon. Thus, an agronomic activity that reduces N_2O emissions by 1 kg ha^{-1} is equivalent to an activity that sequesters 275 kg ha^{-1} CO_2 as soil C. By the same reasoning, in rice paddies production systems that produce Methane and Nitrous oxide in equilibrium (e.g. Hadi et al., 2010); the overall system's effects on global warming can be reduced if management practices create conditions to favour production of Methane rather than Nitrous oxide. Several authors have reported trade-off between Methane and Nitrous oxide in relation to sources of nitrogen fertilizers and water management in rice paddy farming systems.

2.4 Crop field management practices for mitigation of greenhouse gases emissions

Increased food demands necessitate global efforts to increase crop production that ensure food security while at the same time protecting the environment and natural resources through reduced GHG emissions (Burney et al. 2010; Tilman et al., 2011). Hussain et al. (2015) give a short account of several crop management practices with the potential to mitigate emission of greenhouse gases from the rice paddy fields. These include water regimes, management of organic and inorganic fertilizers, tillage practices and selection of rice crop cultivars.

2.4.1 Water regimes

Tyagi et al. (2010) found that midseason and multiple drainage were effective in reducing CH_4 efflux by 36.7% and 41% compared to CH_4 efflux of 346.6 mg/m^2/day recorded in continuously flooded plots. Similarly, Yan et al. (2005) reported 40% and 48% reduction in methane production in rice field following adoption of single and multiple drainages. Similar results were reported by Hadi et al. (2010), The foregoing discussion implies that soil water management in rice fields is not only important to increase productivity, but also to reduce other negative environmental impact of agriculture, thereby achieving CSA.

2.4.2 Fertilizer management

2.4.2.1 Fertilizer application rates

The effects of fertilization on CH_4, and/or N_2O emissions depends on rates of N fertilizers applied and sources of N (inorganic versus organic). Based on extensive review of various studies, Linquist et al. (2012) highlighted an inverse relationship between rate of inorganic N fertilization and CH_4 emission: declining CH_4 emissions with increasing rate of N fertilization. The mechanisms involved for the interaction between inorganic N fertilization rates and net amount of CH_4 emitted in rice paddies are complex (e.g. Cai et al., 2007; Bodelier and Laanbroek, 2004), and beyond the scope of this report. It suffices to note that higher rates of N in the ranges of 100 to 200 kg N ha^{-1} are generally proposed as a strategy for extreme or complete elimination of net CH_4 emissions following N fertilization in the rice paddies system.

These are the same rates that provide maximum yields, which implies that net CH_4 emissions is reduced when N rates matche crop demand (van Groenigen et al., 2010). Furthermore, it is worth to note that optimal rates recommended for reduced net CH_4 emission is based on studies conducted in environments different from those found in Tanzania, or South Nguru Mountains Landscape in particular. Thus, while we recommend adoption of the same higher inorganic N rates as recommended by Linquist et al. (2012) as an interim action, proper trials in representative sites will be needed to establish the optimal N rates that are appropriate for South Nguru Landscape and similar environments in Tanzania. It is also important to caution that too high N rates are economically unjustifiable and environmentally harmful. Studies have demonstrated that N applied in excess of crop demand leads to increased N_2O emissions and other associated environmental problem (van Groenigen et al., 2010; Venterea et al., 2011) besides costs involved to purchase fertilizers. However, to-date there are no studies that have considered the amount of CH_4 and N_2O simultaneously across inorganic (or net GWP), a fact that limit choice of concrete mitigation strategies to reduce GWP with respect to N fertilization in rice systems; this needs further research (Linquist et al., 2012)

2.4.2.2 Effects of N form

The type of mineral N source also affects emission of both CH_4 (Cai et al., 2007) and N_2O (Burger and Venterea, 2011). Studies have indicated that Nitrate based N fertilizers such as Calcium Ammonium Nitrate (CAN) reduce CH_4 emissions relative to urea (Lindau, 1994) as a result of maintained redox potential of the soil (Bouwman, 1991) and/or reduced rice growth and root development[1], as nitrate is denitrified to become unavailable for plant growth (Lindau et al., 1991). However, nitrate based fertilizers are not recommended in rice paddies due to the potential denitrification losses under anaerobic conditions and associated stimulation of N_2O emissions (Cai et al., 2007). Other studies reported less CH_4 emission from rice fields supplied with ammonium sulfate compared with fields supplied with urea or ammonium bicarbonate (e.g. Cai et al. 1997 cited by Cai et al. 2007; Ali et al., 2012). Cai et al. (2007) gave a short

[1]There is direct relationship between increased rice growth and CH_4 production and its respective transport from the soil to the atmosphere (See details in Cai et al., 2007).

account of the biochemical and biological processes behind CH_4 emissions from different N forms[2]. Limited studies have found no differences regarding the effects urea or ammonium sulfate on rice growth and yields, except in sulfate deficient soils (Bufogle et al., 1998 cited by Linquist et al., 2012).

On the other hand, Shang et al. (2011) reported lowest GWP for balanced NPK fertilization than N fertilization alone. Therefore, the ammonium based fertilizers especially ammonium sulfate are recommended in the rice fields over nitrate based fertilizers. Other ammonium based fertilizers that could be used in case of short supply in of ammonium sulfate are urea and ammonium bicarbonate. Nevertheless, from economic point of view, when factors like prices are comparable, the high N content of urea (46% N) compared to ammonium sulfate (21% N) and ammonium bicarbonate (17.7% N) may justify the use of urea over ammonium sulfate. Furthermore, it is important that N fertilizers are applied in conjunction with phosphorus (P) and potassium (K) fertilizers to ensure lowest GWP.

The effects of farm yard manure (FYM) on emission of CH_4 or N_2O are influenced by source of the FYM used. Generally, studies have shown that FYM produces 26% more CH_4 than treatment receiving only mineral N from urea N at the same total N rate (Linquist et al., 2012). Source of FYM and processing can affects its effects on CH_4 emission. Only effects of level of processing have been studied leaving unanswered questions over the effects of different sources of FYM. Composted FYM produce 75% less CH_4 relative to uncomposted fresh FYM (Chen et al., 2011). Similar results have reported for use of composted straw versus fresh straw (Corton et al., 2000 cited by Linquist et al., 2012). Based on these studies it is recommended that FYM manure should only be used when well composted, straw should be managed by surface retention or mulching and making compost instead of either burning or incorporation in order offset GHG emissions in rice fields.

[2]The processes involved in the dynamics of CH4 following application of different N fertilizers is beyond the scope of this report; interested readers are encouraged to consult Cai et al.(2007) for further reading.

Green manure from nitrogen fixing trees is another potential organic fertilizer for IRS. These have not been studied extensively. Available records, suggest that different green manures sources have different effects ranging from reduction in CH_4 emissions as recorded for *Azolla caroliniana* green manure (Bharati et al., 2000) to increase CH_4 emissions recorded for *Sesbania* (192% increase) green manure (Adhya et al., 2000). Given limited studies on green manure fertilization in the IRS, Linquist et al. (2012) recommended the need for evaluation of various sources of green manure for their effects on both rice growth and associated emission of greenhouse gases. Meanwhile, green manure from common multipurpose trees with favourable C:N such as *Leucaena leucocephala*, *Gliricidia sepium* and *Albizia versicolor* are recommended for use alone or in combination with inorganic fertilizers for soil fertility improvement in rice farming systems.

2.4.3 Tillage practices

Tillage practices influences both physical and chemical soil properties (Ahmad et al. 2009; Li et al. 2013). The altered soil properties, in turn, determine processes involved in production of greenhouse gases, reduction-oxidation reactions, the rate of transportation of the greenhouse gases from the soil to the atmosphere and the interactions among these processes (Cai et al., 2007). Tillage break down soil particles increases aeration and expose large surface area of soil carbon which is easily oxidized and attacked by soil microbes that convert it into gaseous carbon dioxide (Sainju et al. 2010).

With a few exceptions, several studies across different countries have reported less CO_2 (e.g. Reicosky and Archer, 2007), CH_4 (e.g. Harada et al., 2007; Ahmad et al.,2009; Pandey et al., 2012) and N_2O (Xiao et al.,2007; Liang et al., 2007; Wu et al., 2009;) emissions in no or minimum tilled rice fields than those under conventional cultivation. Furthermore, other studies have consistently demonstrated that the beneficial effects of no tillage pr minimum tillage is most likely in humid and sub-humid areas than dry areas (e.g. Six et al. 2004). Thus, considering overall effects on CO_2, CH_4 and N_2O fluxes; no tillage or minimum tillage practices in rice farming system provide an overall reduction in GWP, which suggests that the adoption of not tillage or minimum tillage are beneficial in GHG mitigation and climate-smart agriculture and needs to be promoted in rice-based cropping systems.

2.4.4 Selection of rice cultivars

Hussain et al. (2014) presented several studies that have reported huge variability in CH_4 emission and overall GWP among different rice cultivars in different environments. The observed variations in CH_4 emission among rice cultivars has been attributed to inherent differences in among cultivars in CH_4 emission have been attributed to the variation in CH_4 production, oxidation, and transport capacities (Aulakh et al. 2002; Lou et al. 2008). Difference in gas conductance as related to O_2 release in the rhizosphere is among the key characteristics that determine difference in CH_4 emission; tiller density, root biomass and total biomass are among different rice cultivars (Wang et al., 1997; Aulakh et al., 2002; Ma et al., 2010; Li et al., 2013). Stronger fibrous root system is considered to be an important phenotypic feature for selection of rice cultivars with lower GWP. Apart from lower GWP, the stronger root system enhances resistance to environmental stresses and increase crop yield (Mei et al. 2009, 2012; Li et al. 2013). In this regard, Zhang et al. (2009) and Jiang et al. (2013) reported significantly higher root oxidation and lower CH_4 emission in super rice than traditional varieties. Other studies have reported less CH_4 in rice cultivars maturing in 3 months than cultivars maturing after 4 months (Setyanto et al., 2000). This implies that shorter season length is the most conclusive criterion for selection of low-emitting rice cultivars. Thus, super rice variety and other early maturing rice varieties recommended for planting in order to enhance mitigation of greenhouse gases emission from rice farming systems.

2.5 Soil fertility depletion in sub-Saharan Africa

Several authors have given a detailed account of soil fertility depletion across the Sub-Saharan Africa (SSA). Across SSA countries, soil-fertility depletion in smallholder farms, especially nitrogen (N) and phosphorus (P) deficiencies; is the major biophysical root cause of declining per capita food production (Sanchez *at al*., 1997; Sanchez, 2002). Smaling et al. (1997) seminal paper on nutrient imbalance presented alarming nutrient losses in cultivated lands in Africa: 4.4

million tons of nitrogen (N), 0.5 million tons of phosphorus (P), and 3 million tons of potassium (K) every year. Several authors (e.g. Vanlauwe and Giller, 2006; Kobo et al., 2010) have criticized the generalized conclusions that soil nutrient depletion culminate in nutrient imbalance at aggregated scale. They pointed to cases where nutrient depletion does not lead to nutrient imbalance due to possibility for nutrient released from the parent material. However, all analyses have converged on the fact that continuous cropping requires nutrient replenishments to ensure sustainable crop production (Sanchez *at al*., 1997; Vanlauwe and Giller, 2006).

Thus, dwindling crop yields is expected to continue unless measures to address soil-fertility depletion are developed and implemented effectively. Some lessons can be drawn from Asian green revolution of 1960s where discoveries of high yielding varieties of rice and wheat resulted in increased crop yields, improved living standards of the people and economic development (Ejeta, 2010). Additional increase in productivity can be achieved through improved crop management technologies (e.g. various combinations of organic and inorganic fertilizers) and physical technologies such as irrigation infrastructure, research and extension services, and enabling government policies (Sanchez *at al*., 1997).

2.6 Soil fertility replenishment technologies

Technologies for soil fertility replenishment include constant applications of mineral fertilizers, various organic plant nutrient sources, and renewable soil fertility management practices such as various agroforstry practices with nitrogen fixing trees/shrubs and nutrient accumulating shrubs such as *Tithinia diversifolia* (Bekunda et al., 2010; Babajide et al., 2012); and conservation agriculture (CA) that combine renewable soil fertility management practices with no or minimum tillage practices. Each of the soil fertility replenishment technologies has its inherent strengths and challenges that are dynamic across different environmental, cultural and social contexts (Ojiem et al., 2006; Ojiem et al., 2007; Millar and Connell, 2010). These facts have paved the way to evolution of integrated soil fertility management (SFM) practices, which entail judicious combination of the different soil replenishment technologies together with improved germplasm and local adaptations (Bationo et al., 2008; Vanlauwe et al., 2011).

Application of mineral fertilizers and agroforestry are further described in the subsequent sub-sections.

2.6.1 Application of mineral fertilizers

Apparently, application of mineral fertilizers is the most common way to replenish soil fertility and maintain crop production. Proper usage (appropriate dosage and right timing) of inorganic fertilizers have no any harm to the environment (Sanchez *at al*., 1997; Sanchez, 2002). However, most farmers in Sub-Saharan Africa (SSA) can only apply suboptimal amount or not at all due to inadequate cash income as a result of widespread poverty (Mtambanengwe and Mapfumo, 2005). Gruhn et al. (2000) reported an average mineral fertilizer usage of 9 kg ha^{-1} in the SSA compared to the global average of 98 kg ha^{-1}. Recent resurgence of agricultural inputs subsidy programs has failed to reverse the situation as they tend to exclude the poor and poorest ostensibly they were established to help. For example, recent studies on agricultural inputs subsidies programmes in Tanzania including villages in the South Nguru Mountains Landscape (Aloyce et al., 2014) and Malawi (Ricker-Gilbert, 2011) found that subsidized fertilizers were targeted to wealthier households who had community and political connections.

The immediate causes of inadequate fertilizer application in the SSA include high cost, inadequate access to credit, delivery delays and variable returns. Sanhez (2002) noted that, in Africa, fertilizers cost two to six times as much as those in Europe, North America, or Asia. He further noted that within each of SSA country the mineral fertilizer prices increase as you go from the ports to the interior where rural areas are located. For example, Sanchez et al. (1997) found that indicative costs of a metric ton of urea were U.S. $ 90 in Europe, $120 when delivered in the ports of Mombasa, Kenya, or Beira, Mozambique, $400 in the interior of Kenya, $500 in Uganda and $770 in Malawi.

2.6.2 Agroforestry as sustainable land management practice

2.6.2.1 Definition of agroforestry

Agroforestry (AF) is defined as land-use systems in which woody perennials (i.e. shrubs or trees) are deliberately grown in association with herbaceous species (i.e. crops or pastures) with or without livestock (Anderson and Sinclair, 1993). Trees may be grown in the field at the same time as crops such as in an intercropping system or in a time sequence such as trees grown in a fallow for restoration of soil fertility. AF has been proven to be a sustainable alternative to traditional shifting cultivation, and/or intensive monoculture agricultural systems that are condemned for negative environmental impacts. Unlike industrial plantations where trees are grown to meet wood or timber demand, agroforestry trees/shrubs are grown for multiple roles (Young, 1997; Malézieux et al., 2009)

2.6.2.2 Classification of agroforestry systems

AF systems are grouped in two broad categories (Sanchez, 1995; Cooper et al., 1996):

1) **Simultaneous systems** where trees/shrubs and crops are grown together in the same land unit in different spatial arrangements; examples include trees on croplands, hedgerow intercropping, intercropping in perennial-tree–crop stands and multi-strata systems;
2) **Sequential systems** where trees and crops are grown in rotation; examples include rotational bush fallow or planted tree fallows followed by crops. However, some systems, such as *taungya*, rotational hedgerow intercropping, rotational woodlots, and relay planted tree fallows in crops merge the characteristics of both simultaneous and sequential systems.

However, there are systems such as rotational woodlots that combine functional features of both simultaneous and sequential agroforestry systems, which is further describe below.

2.6.2.3 Rotational woodlot system as an intermediate agroforestry system

Rotational woodlot system entails three distinct management phases symbolizing functional features of both sequential and simultaneous AF systems (Kimaro, 2009; Nyadzi, 2004). The three phases of the rotational woodlot system are presented in Figure 1.

a) Initial tree establishment phase

Tree establishment phase is the first phase of rotational woodlot system, which signifies typical simultaneous agroforestry system where trees and crops are gown together in the same land unit. During this phase, tree and companion crops are intercropped for 2 to 3 years just before crop yield declines to uneconomical levels due to adverse competition of the associated trees. The main objective of this initial phase is to establish trees while producing food crops. Therefore no effort is made to manage trees for minimization of the interspecific competition.

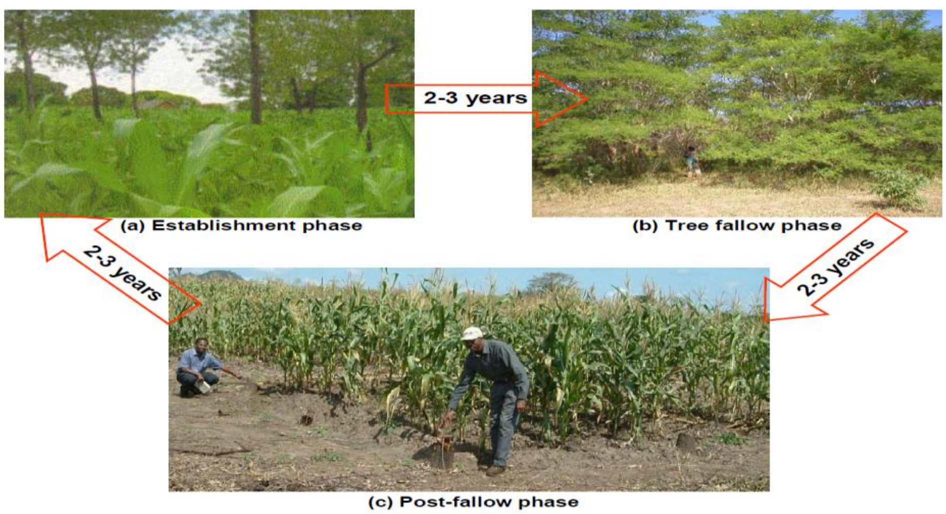


Figure 1: Pictorial presentation of the three phases of rotational woodlot system (Source: Kimaro, 2009)

The current practice is to halt cultivation once the trees close their canopy to become more competitive. However, especially in humid areas where competition for water is less relevant, crop production can be extended to the “so called tree fallow phase” by substituting shade tolerant crops such as ginger (*Zingiber officinale*), pineapple (*Ananas comosus*), greater yam

(*Dioscorea alata*), taro palagi (*Xanthosoma sagittifolium*) and true taro (*Colocasia esculenta*); for conventional light demanding field crops (Valenzuela et al., 1991; Newman et al., 1997; De Clerck et al., 2000).

b) Tree fallow phase

Tree fallow phase is the second in the rotational woodlot system; it resembles sequential agroforestry system where trees and crops are grown separately in sequence. In this phase, trees are left to grow alone without intercropping in order to avoid competition for water and light. This phase takes 2 to 3 years during which little or no management is required to maintain trees while restoring soil fertility through nutrient cycling processes, and/or nitrogen fixation depending on the tree species used. Livestock may be allowed to graze on the herbaceous plants within the woodlots especially during dry season when all other grazing lands become exhausted. The practice of reserving fodder under the woodlot is known as *Ngitili,* a traditional *silvopastoral* system in western Tanzania in which farmers reserve part of the grazing land at the beginning of the rainy season to provide high nutritive pasture during the dry season when supply from unreserved areas is depleted. In addition, the woodlot can provide an apiary site where beekeeping may be practiced. This phase ends when trees have grown to a desirable size; the woodlot is cleared to supply wood for various uses such as building poles, firewood for domestic use and tobacco curing. To ensure adequate nutrient cycling, foliage biomass should be retained on site as green manure.

c) The post fallow phase

The final phase of the woodlot system cycle is a post-fallow period in which crops are grown between tree stumps to benefit from the ameliorated soil conditions after harvesting trees from the woodlot. For tree species that sprout, coppice shoots are regularly pruned to minimize above ground competition and are incorporated into the soil or used as fodder. The cycle starts afresh after 2 to 3 years of sequential cropping when crop yield decline to unacceptable levels as a result of nutrient depletion through repeated harvesting.

For nitrogen fixing tree that coppice, the post fallow phase may not be conspicuous. For example, Vyamana (2012) suggests an overlap of phase 3 and phase 1 of the rotational woodlot when nitrogen fixing trees with coppicing ability (e.g. *Albizia versicolor* and *A. harveyi*) are used. In this case, phase 3 constitutes coppice establishment phase, similar to tree establishment phase, where coppices from the stumps are left to grow together with crops until the coppices closes canopy after 2 – 3 years. The cycle continues after harvesting of the mature coppice trees. The key additional benefit of using nitrogen fixing tree/shrub species is the relatively high gain in soil fertility improvement resulting from both nutrient cycling and nitrogen fixation processes. Non-nitrogen fixing trees/shrubs are less efficient in improving soil fertility as they rely on nutrient cycling alone with little possibility to improve nitrogen availability. Given the fact that nitrogen is among the most limiting nutrients in the tropical soils, **use of nitrogen fixing trees/shrubs in rotational woodlots is highly recommended**.

2.6.2.4 Tree-crop interaction in agroforestry

Tree-crop interaction in AF refers to the effect of one component of the AF system on the performance of another component and/or the overall system (Nair, 1993) on the basis of pattern of utilization of spatial, temporal and physical resources (Jose et al., 2000). Interactions in AF systems are continuous, rather than seasonal as in annual systems, and are determined by the system's tree/shrub component due to their perennial and dominant nature (Rao et al., 1998).

Based on the effect and nature of biophysical interactions, AF interactions can be grouped into three broad categories (Jose et al., 2004; Ong and Rao, 2001):

1) **Neutral interaction:** trees and crops exploit the same pool of resources so that increase in capture by one species results in a proportional decrease in capture by associated species.
2) **Positive or facilitation interaction or complementarity:** trees capture resources that are unavailable to crops leading to increased overall capture and system productivity. This

can result from either increased growth source (nutrients, light and water) capture or improved source use efficiency.

3) **Negative or antagonistic interaction:** association of trees and crops results into serious reduction in the ability of one or both species to capture growth resources.

Thus the ecologically sound, economically viable and socially acceptable AF systems must be one that maximize positive interactions (complementarity) while at the same time minimizing negative interactions (competition) among the AF components (Jose et al., 2000; Garcia-Barrios and Ong, 2004). The underlying principle, especially in simultaneous AF systems, is growing of trees/shrubs whose resource requirements differ from that of the companion crop. However, it is important to note that the biophysical interactions in AF are complex and are determined by factors related to tree/shrub and companion crop morphological and biological characteristics, environmental factors such as climate and soil characteristics (Garcia-Barrios and Ong, 2004), some of which can be manipulated by the land-user (Schroth, 1999). This suggests the need for understanding of the biophysical processes involved in the allocation of growth resources (light, soil nutrients and water) among different tree/shrub and companion crop species (Ong et al., 1996; Rao et al., 1998).

2.6.2.5 Factors affecting tree-crop interaction in agroforestry systems

a) Site characteristics

Site characteristics such as climate and soil properties (physical and chemical) can affect the nature and extent of tree/shrub-soil-crop interaction. Tree-crop interaction processes are dominated by soil fertility, weed control and competition for growth resources where the relative magnitude of interactions determines their net effect on crop yields. Table 4 summarizes the major interaction processes with respect to agro-climatic conditions as identified by Rao et al. (1998).

Generally, improvement in soil nutrient status for both simultaneous AF systems such as hedgerow intercropping and sequential AF systems such as improved fallow; is mainly through nutrients released from mineralization of the pruned foliage biomass. It has been proven that nutrient contributions from AF systems are positively correlated to the amount of foliage biomass added to the soil. Furthermore, foliage yields are higher in humid agro-climatic conditions and least in semiarid areas.

Table 2: Selected processes in tree-soil-crop interactions in hedgerow intercropping systems and their net effect on crop yield in different climates, assuming a moderately fertile soil

Interaction process	**Semiarid (< 1000 mm rainfall)**	**Sub humid (rainfall between 1000 and 1600 mm)**	**Humid (rainfall >2000 mm)**
Nutrient availability to alley crops	Positive (S to L)	Positive (L)	Positive (L)
Soil chemical changes	Positive (S)	Positive (S)	Positive (L)
Soil physical changes	Positive (S to L)	Positive (S to L)	Positive (S to L)
Soil biological changes	Neutral	Positive (S to L)	Positive (L)
Soil conservation	Positive (S to L)	Positive (L)	Positive (L)
Water availability to alley crops	Negative (L)	Neutral/negative (S)	Neutral
Shading	Neutral	Negative (S)	Negative (L)
Crop yield	Negative (S to L)	Positive (S to L)	Positive (S to L)

Key: S = Small; L = Large

Source: Modified from Rao et al. (1998)

Improvement in soil nutrient status under hedgerow intercropping is more pronounced in sub-humid and humid tropics but negligible or absent in the semiarid tropics (Sanchez and Jama, 2002). However, there is a scope for improving quantity of foliage produced in semiarid areas especially through selection of tree species that are adapted to semiarid areas (Kumar et al., 1998; Kimaro, 2009). Therefore, proper tree species selection is of paramount importance in determining success or failure of on-farm tree planting initiatives.

b) Tree leafing phenology

It has been hypothesized that differences in tree phenology could result in temporal complementarity. For example, trees like *Faidherbia albida* with its reverse leafing phenology avoids competition with companion crops because they have peak demand for water and soil nutrients at a different time from that of the crops (Ong et al., 1992). Competitive influence of trees/shrubs is minimized when leaves are lost during the cropping season leading to temporal complementarity.

Timing and extent of leaf shedding and replacement during the annual cycle varies between species (Muthuri et al., 2005) and determines the pattern and rate of soil water abstraction and hence effects on associated crops (Broadhead et al., 2003). Trees and shrubs can be grouped into four different leaf phenological groups (Eamus and Prichard, 1998; Pugnaire et al., 1999):

(i) **Evergreen species**: retain a full canopy throughout the year and leaf turnover is continuous;

(ii) **Brevi-deciduous species**: exhibit brief reductions in canopy size which never exceed 50% and do not occur every year;

(iii) **Semi-deciduous species:** show reductions in canopy density of at least 50% every year;

(iv) **Deciduous trees:** these are trees such as miombo tree species that shade all leaves for at least one month every year.

The relationship between tree leafing phenology and nature of interaction is that trees are more competitive when they have more leaves than when the leaves are (Muthuri et al., 2005). Thus, leaf shading is only beneficial to companion crops if it is synchronized with period of active crop growth. This implies that temporal complementarity can be achieved by choosing tree/shrub species that are deciduous for at least part of active growth of the common field crops such as *Faidherbia albida*.

c) Tree/shrub age and spacing

In simultaneous AF systems, crop yields under tree canopies decreases progressively with tree age due to combination of competition for light as a result of shading by expanding tree/shrub crowns, and competition for water resulting from developed tree/shrub root system (Yin and He, 1997; Nyadzi, 2004). Besides variation between tree/shrub species, the onset of competition in simultaneous AF system depends on spacing at which the trees/shrubs are planted, which determine the rate at which trees produce shade or roots per unit farm area. Thus, the pattern of the effects of tree age on the nature and magnitude of tree-crop interactions varies with planting density (widely spaced trees taking longer to reduce crop yields) (Yin and He, 1997; Muthuri et al., 2005) and is influenced by climate and shade tolerance of the field crop grown. For example, in humid climate where soil moisture is not limiting; intercropping multipurpose trees/shrubs with shade-tolerant crop plant species such as ginger (*Zingiber officinale*), pineapple (*Ananas comosus*), greater yam (*Dioscorea alata*), taro palagi (*Xanthosoma sagittifolium*) and true taro (*Colocasia esculenta*) (Valenzuela et al., 1991; Newman et al., 1997; De Clerck et al., 2000); instead of shade-intolerant species leads to increased yields as a result of improved microclimate. Thus, at the peak of competition for light for most common field crops, it is possible to substitute shade tolerant vegetable crops for conventional light demanding field crops as the trees grow larger and shading intensity increases.

d) Tree/shrub management

(i) Planting spacing and tree pruning

Tree/shrub management practices such as root and shoot pruning (Ong et al., 2007); selection of deciduous tree/shrub species with deep root system that use little water during the dry season (Huxley et al., 1989) can minimize their competition with crops. These management practices are implemented with the aim of ensuring that trees/shrubs capture only those resources not used by field crops. As a general rule, pruning can be expected at the age of above 3 or 4 years. In order to ensure balanced tree growth, the guiding principle is that the maximum pruned height from the ground should not exceed one third of the total tree height. Other technical considerations for pruning operations are as follows (Tengnas, 1994):

a) Pruning should be scheduled at the end of the rain season to avoid the risk of fungal infections;
b) Proper and sharp tools such as curved hand saws or sharp *pangas* should be used;
c) Avoid blunt tools as they result into damage of the stem such as debarking; and
d) Branch should be pruned by flush cutting to the stem to avoid leaving stumps of the branches on the stem

(ii) Integrating trees with less competitive shrubs

As noted earlier, planting trees at wide spacing can reduce their competitive effects. However, too wide spacing will impair the ability of trees to improve soil fertility due to less foliage productions. On the other hand, integrating multipurpose trees, planted at square of 4 m x 4 m; with less competitive AF shrub species such as *Tephrosia vogelii, Crotalaria ochroleuca* and *Tithonia diversifolia;* planted at spacing of 60 cm within row and 90 cm between rows; avoids the negative effects of trees on crops while enhancing crop yields substantially. The recommended arrangement of trees and the less competitive shrubs is shown in Figure 2.

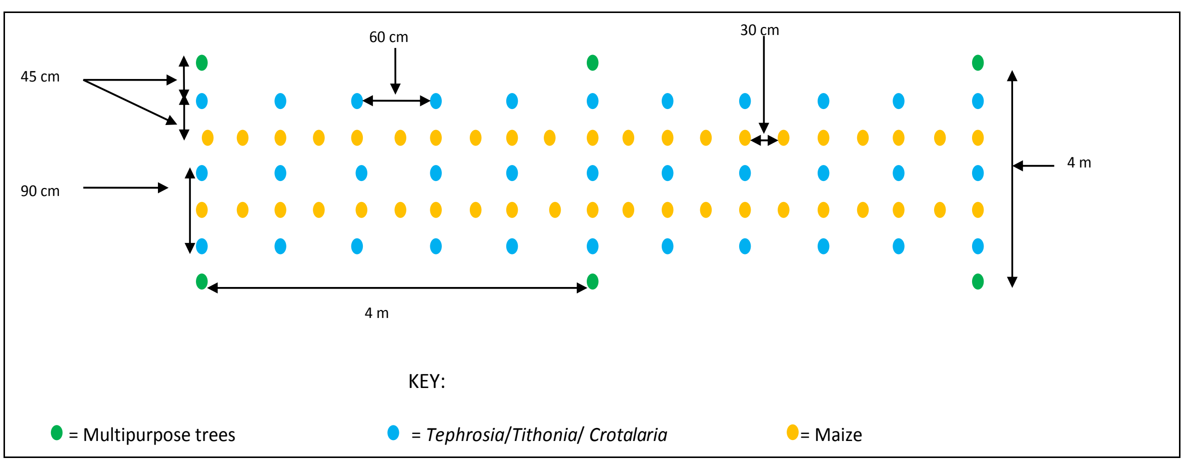


Figure 2: Schematic diagram showing typical configuration of trees, maize and less competitive soil improving shrubs (Source: GLOWS-FIU, 2015)

Although these shrubs can improve soil fertility even without integrating with widely spaced trees (Ngegba et al., 2007; Odhiambo et al., 2010), they cannot produce wood to meet the increasing demand for firewood, poles and timber. Thus, integrated system of trees and less competitive shrubs has positive effects on crop yields while at the same time producing firewood and other wood products.

3. METHODS

3.1 Description of the study area

3.1.1 Climate

An overall account of precipitation in South Nguru Mountains Landscape is provided by GLOWS-FIU (2014) as summarised in Figure 3.

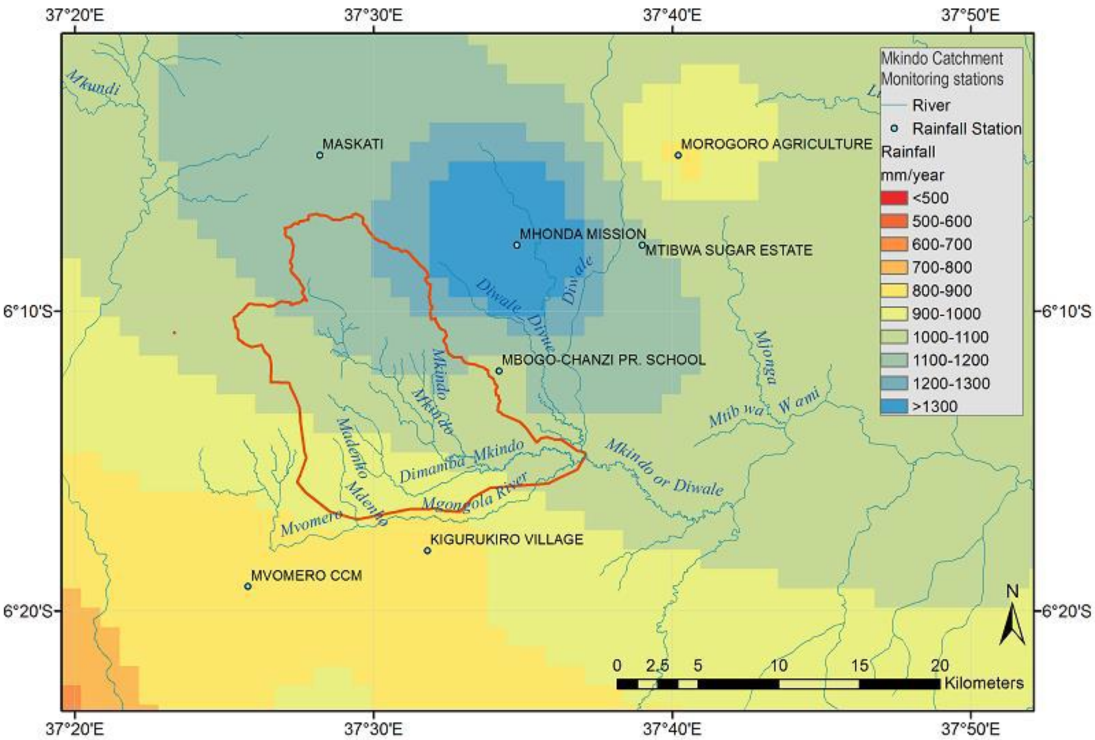


Figure 3: Annual rainfall isohyets averaged over the period 1950-2010 of some parts of South Nguru Mountains Landscape (Source: GLOWS-FIU, 2014)

Precipitation is influenced by altitude and aspect. At higher altitude (900 ~ 1500 m or above) on the windward side (eastern side) are characterised by clouds almost throughout the year. These areas receive the highest bimodal rainfall in the landscape. The rainfall ranges around 2000 mm year^{-1} increasing up to 3000 mm to 4000 mm at 2000 m a.s.l (Lovett and Pócs, 1993 cited by Menegon at al., 2008). The leeward side of the highlands receives much less precipitation which decrease further s you move from highlands to lowlands. As a result, the leeward side is characterised by much drier natural vegetation occurring that ranges from moist deciduous forest to thorny acacia woodlands.

At lower altitudes (< 800m) annual rainfall decreases from the highlands to lowlands and it tend to change from bimodal to unimodal regime, much of it falling between March-May (*masika* rains), with some in December-February (*vuli* rains). Rainfall decreases further as you move from windward (e.g. Mkindo village) to leeward lowlands (e.g. Bwage).

The South Nguru Mountain Landscape has a characteristic tropical climate which is influenced by altitude and aspect. In the lowlands the minimum and maximum temperatures range from 18 - 22 °C and 26 – 32 °C, respectively. At higher altitudes temperature may go down by 5 or 10 °C.

3.1.2 Landforms, hydrology and soils

The project area consists of ten land mapping units (Figure 4). The study area is traversed by major rivers namely Chazi, Diwale, Mkindo, Mgongola, Mjonga and Divue. The soils in the project area range from highly weathered oxisols in Ndole, Mvomero, sand around Msolokelo to clay loams with imperfect drainage around Mkindo and Mziha. Major soil types in the project areas include cambisols, luvisols, and nitisols (FAO, 2006).

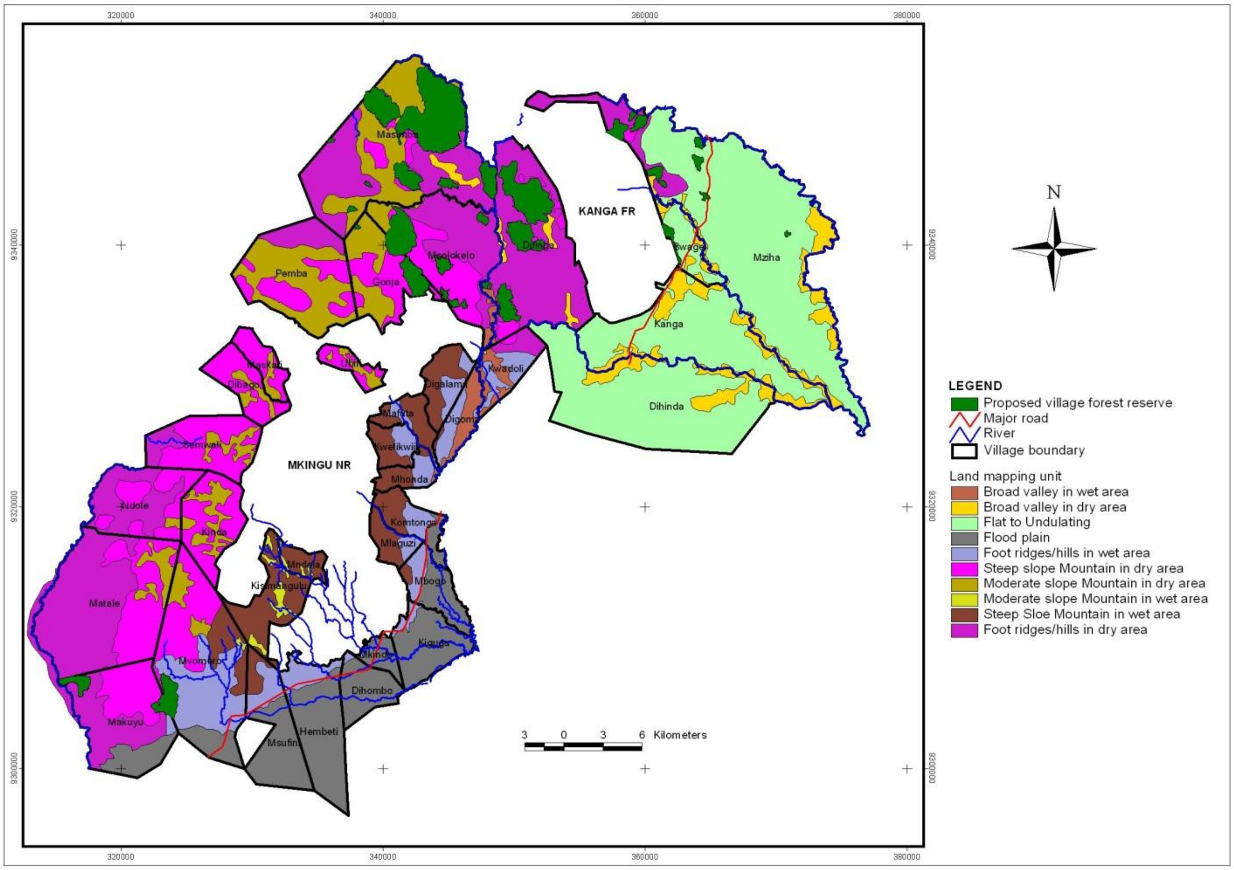


Figure 4: Major land mapping units of the South Nguru Mountains Landscape in Mvomero district, Tanzania

3.2. Analytical framework

The analytical framework for feasibility analysis of climate smart agricultural options in South Nguru Mountains Landscape is presented in Figure 5. The framework amalgamates similar frameworks developed and practically demonstrated by Jones (2002) and Ojiem et al. (2006). The use of the framework is justified by its proven robustness and previous practical application in identification and quantification of range of factors that affect biophysical performance and adoption of soil management practices (Jones, 2002; Bravo-Ureta, 2006; Ojiem et al., 2006). The framework consists of two major domains, namely, agro-ecological factors and socio-cultural factors. The subsequent description of the agro-ecological factors and socio-cultural factors domains follows Ojiem et al. (2006) and Jones (2002) in that order.

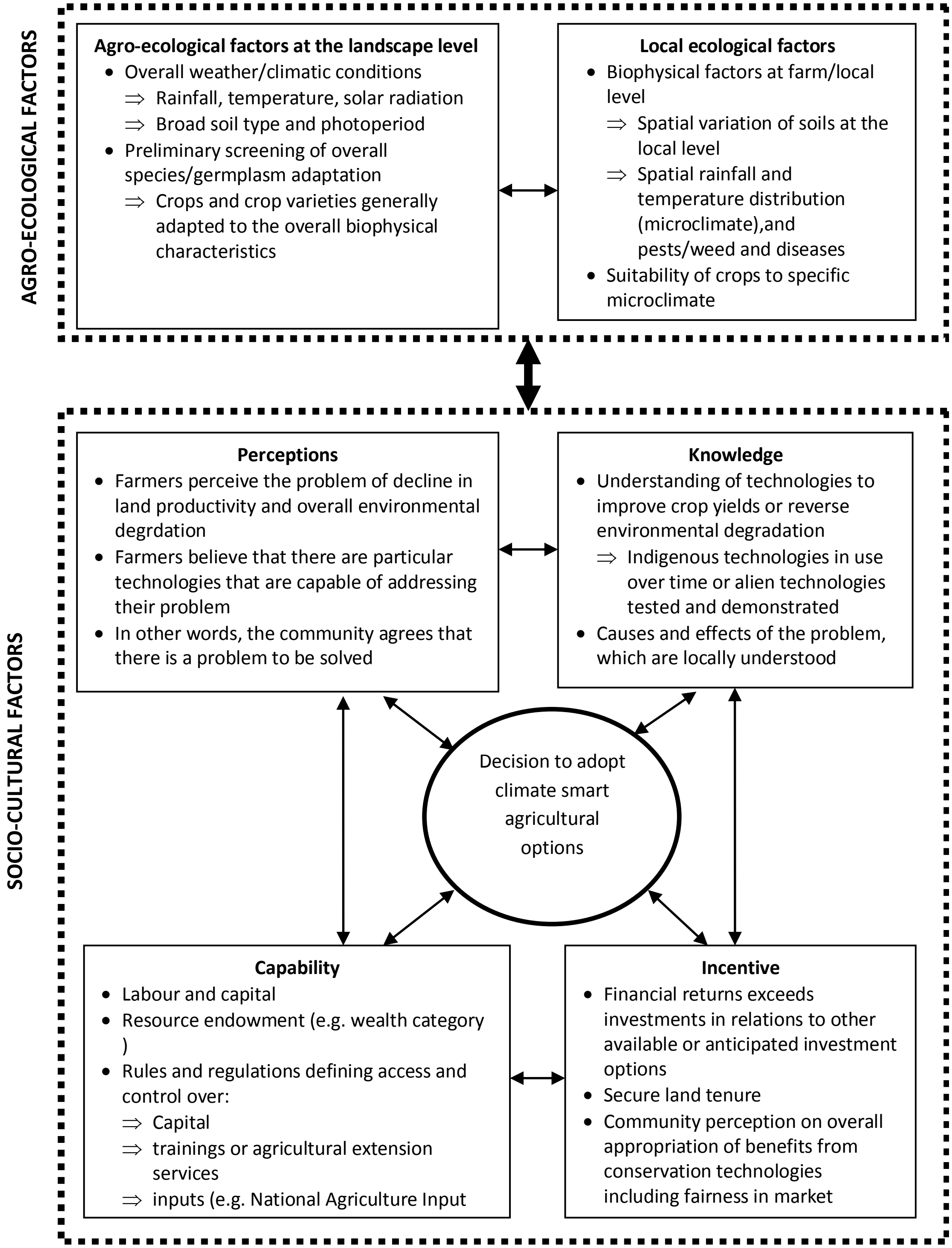


Figure 5: Analytical framework for feasibility analysis of climate smart agriculture options in South Nguru Mountains Landscape, Mvomero district (Source: Adapted from Jones, 2002; Ojiem et al., 2006)

3.2.1. Agro-ecological factors

Agro-ecological factors connote a dynamic association of naturally occurring plant and animal communities that are in constant interaction with physical and chemical environments on one side, and human activities on the other (Altieri, 2002 cited by Ojiem et al., 2006). Ojiem et al. (2006) categorize two levels of agro-ecological factors: 1) the broad landscape level to which different crops/crop combinations of interest must be adapted prior going to more detailed discriminatory analysis; and 2) the biophysical factors at farm level.

3.2.1.1. Landscape level

Variables included in agro-ecological factors at the landscape level are overall precipitation, temperature, solar radiation, photoperiod, soil type, etc. averaged over the entire landscape. However, in actual sense, a large landscape such as South Nguru Mountains Landscape exhibits different local weather/climatic conditions, plant communities (e.g. GLOWS-FIU, 2014). For example, precipitation regime of the South Nguru Mountains Landscape is characterized by high rainfall in highlands than lowlands; this is further differentiated by relatively high rainfall in the windward sides under the influence of the moist winds from the Indian Ocean than leeward sides. Conversely, at lower altitudes such as in Digoma or Mkindo villages rainfall decreases and tends to change from typical bimodal rainfall regime found in the windward highlands to unimodal rainfall regime.

3.2.1.2. Local ecological factors at farm level

More reliable discriminatory analysis of the suitability of crops/crop combination has to be done at the lowest possible landscape scale, which entails local ecological factors. Local ecological factors are more precise biophysical variables at the farm level that determine agronomic performance of crops/crop combinations. These include physical and chemical soil properties. Analysis at the farm or sub-landscape level discriminate few crops/crop combination that are likely to perform in the area based on their biophysical requirements.

3.2.2. Socio-cultural factors

Based on Jones (2002), socio-cultural factors consist of four major elements: perceptions, knowledge, incentive and capability. The interrelationships between these elements are further described.

3.2.2.1. Perceptions

In order for farmers to adopt the proposed climate smart agricultural (CSA) options they should first of all perceive existence of the real problem ostensibly envisaged to be solved or alleviated. FAO (2010) suggests that climate smart agricultural options intend to improve and sustain productivity, adaptation to climate change and mitigate causes of climate change. Therefore, for communities to accept CSA options it must perceive problems related to decline in crop yields or soil fertility, changing weather, and/or deforestation or forests degradation especially its linkages to availability of environmental services such as water flow and forest products that they need to live.

3.2.2.2. Knowledge

Farmers will be willing to accept CSA options if they have understanding of similar practices both indigenous and alien capable of addressing the perceived problems of decline is crop yields, soil fertility and overall environmental degradation. In this case, alien practices will only be accepted if they are preceded by adequate participatory practical training (Young and Fosbrooke, 1960 cited by Rutatora et al., 1993; Ngambeki and UNECA, 2003; Carswell, 2006).

3.2.2.3. Incentive

Incentive to adopt CSA options will depend on inherent monetary gains, and a wide range of contextual issues. They key factors under this domain are access to and control over land resource i.e. security of land tenure, relative profitability of other possible investment options such off-farm activities, nature and fairness of market interactions such as perceived fairness to the farmers.

3.2.2.4. Capability

Capability refers to ability to make decisions and implement them. In this case the decision to be made is either to adopt CSA or not, which is influenced by access to capital and labour needed to implement specific options (Jones, 2002). Equally important are social relations that determine access and control over resources at the household such as culturally constructed gender relations, and at the community level such as rules and regulations governing credit schemes (GLOWS-FIU. 2013). Both at community and household level; capability denotes ability to make decisions and effect action within the limits of financial, social networks and human capitals. Thus, CSA options that are compatible with or that integrate means to alleviate existing limitations with respect to physical, financial and social resources are likely to be successful. Furthermore, it is worth noting that communities are in fact highly differentiated (Ellis and Allison 2004). This implies that within the same communities different social groups could have different opportunities or limitation regarding their capability to adopt CSA options.

3.3. Study approach

3.3.1. Stakeholder consultation and overall sampling framework

A stakeholder consultation workshop was conducted to bring together key stakeholders of the landscape management (Annex 2). During the workshop, participants were divided into groups of professionals and farmers, and facilitated to define the four general agro-ecological zones of the landscape and allocate the project villages in respective zones of the landscape. The stakeholders were guided to categorise villages into pre-determined strata, which was accomplished in two stages. In the first stage, the landscape was divided into two broad strata: 1) wet areas with rainfall of 1000 mm and above per annum and above, and 2) dry areas with rainfall less than 1000 mm per annum (GLOWS-FIU, 2014). In the second stage, each broad ecological zone was further subdivided into two (2) sub-strata based on altitude: 1) lowland/downstream, 2) highland/upstream.

With the help of a secretary, each group captured their views onto a flip chart. After their individual small group discussions, a plenary session was convened where each group reported and defended their answers. The reasons for allocating different villages in different agro-ecological zone were explained and their validity confirmed from local experts who were present and subsequently verified with the existing records. This process resulted in a harmonized allocation of the village in respected agro-ecological zone that was agreed by both professionals' and farmers' groups as presented in Table 3. It should be noted that this categorization of the villages was meant to preliminary guidance for selection of study villages and further biophysical analysis based on available published data sources (e.g. GLOWS-FIU, 2014). Detailed biophysical study was informed by more in-depth spatial analysis of available rainfall, altitude and soil data as presented sub-section 3.3.2.

Table 3: Distribution of villages by agro-ecological zones within the South Nguru Mountains Landscape as defined during stakeholder consultation workshop in Turiani, Tanzania

Physiography/Altitude	Climate	Villages
Highland	Dry	Mziha, Pemba (Nyakonge sub-village), Masimba (Manyanga), Bwage, Matale, Makuyu
Highland	Humid	Dihombo, Misufini, Digalama, Hembeti, Mndela, Medina, Msolokelo (Gombero sub-village), Maskati (Dibago), Kisimaguru, Kwelikwiji, Gonja, Pemba, Kanga, Mafutaha, Dihinda, Ubiri, ,Komtonga, Mlaguzi, Mbogo, Kigugu, Digoma, Mvomero, Semwali, Mhonda
Lowland	Dry	Mziha, Pemba (Kombe), Msolokelo (Msolokelo), Bwage, Makuyu, Masimba, Matale
Lowland	Humid	Dihombo, Digoma, Kigugu, Hembeti, Kwadoli, Mkindo, Kmtonga, Msufini, Mbogo, Kanga, Dihinda, Difinga, Bwage, Kigugu, Mvomero

Several villages[3] such as Pemba and Msolokelo villages were listed in both wet and dry agro-ecological zones as they had their patches falling in the both zones. It was agreed to group each

[3]These villages are listed in their major agro-ecological zone but marked with a star symbol (*)

village based on one dominant agro-ecological zone so that there were no villages allocated to dry-highland agro-ecological zone. However, the final GIS based agro-ecological zoning considers different agro-ecological zones falling in each village as described in sub-section 3.1.2 (Figure 4).

For the socio-economic study, it was decided that two villages be randomly sampled from the wet-highland agro-ecological zone and one village from each of the wet-lowland and dry-lowland agro-ecological zones. Sampling of the villages was done in the same workshop where, for each zone, each respective village name was listed on a manila card. The manila cards were shuffled with their written face downwards and one card drawn and read loudly to all participants. Consequently, Mndela and Kinda villages were randomly selected to represent wet-highland agro-ecological zone whereas Digoma and Bwage villages were randomly selected to represent wet- and dry- lowland agro-ecological zones, respectively (Figure 4).

3.3.2. Biophysical study

3.2.2.1. Land characterization and mapping

In order to establish the land qualities needed for sustained production of the selected crops/land utilization types, soil survey was carried out. Land mapping units representing major topographic units in the area were generated for soil sampling. The initial land mapping units were refined by considering spatial variation of annual rainfall and altitude. A total of 10 broad landforms were classified in the field and used to delineate ten land mapping units. These landforms are: Flood plain, Flat to Undulating, Broad valley in dry area, Broad valley in wet area, Foot ridges/hills in wet areas, foot ridges/hills in dry areas, moderate slopes mountain in wet area, Moderate Slopes Mountain in dry area, steep slopes mountain in wet area and steep slope in dry area (Figure 6). Delineation of land mapping units was done using ASTER DEM, Digital topographic maps and Land use/cover maps in GIS. The generated land mapping unit map was verified in the field and the final map was produced and used as the base map during the soil survey. Soil were augered in each land mapping unit except the foot ridges/hills of both wet and dry areas which were represented by same Auger observation site (s). Soil augering was done at 0 to 15 and 15 to 30 cm depth to determine soil variations and demarcation of soil units. After demarcation of soil units composite surface soil samples were collected in each selected soil units. About 10 sub soil samples were collected at the depth of 0 to 15 cm depth in a representative area of approximately 0.25 ha. The subsoil samples were then mixed to form a composite sample representing a soil unit. A total of 27 soil samples were collected for soil physical and chemical analysis. Auger observation points for respective soil units were georeferenced with GPS receiver. The sampled soils were taken to the SUA soil laboratory for analysis.

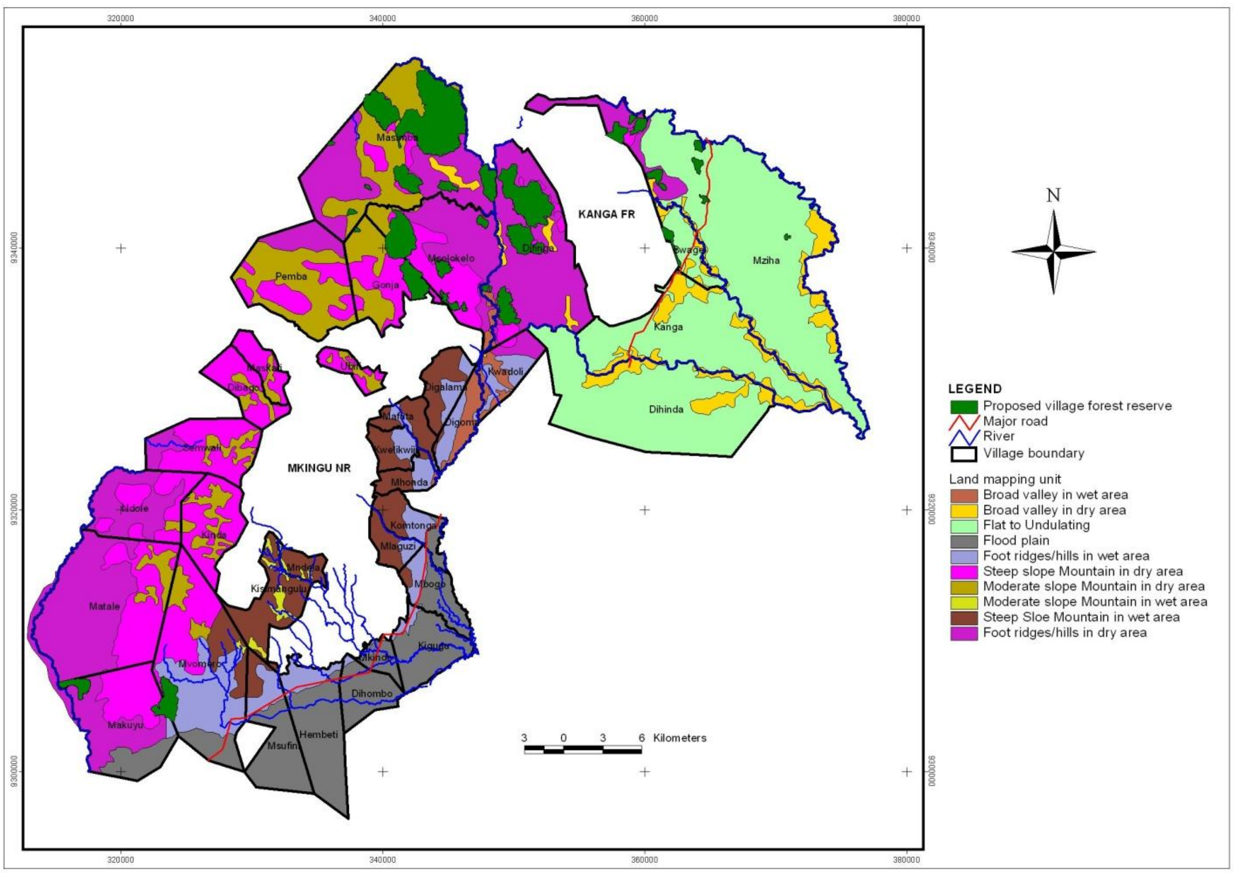


Figure 6: Soil mapping units with village boundary, rivers and proposed village forest reserves in South Nguru Mountains Landscape in Mvomero district, Tanzania.

3.2.2 Land suitability assessment

Land evaluation is the process of assessing the possible uses of land for different purposes. Land suitability assessment is a method of land evaluation, which measures the degree of appropriateness of land for a certain use.

The present work intended, among others, to determine land suitability in the project area for maize, rice, sunflower, beans, cowpea, cocoa, avocado, banana, mango citrus, tomato, cassava, sesame, *Grevillea robusta*, cardamom and *Tectona grandis* (teak) cultivation. This assessment was based on a number of biophysical variables including rainfall, temperature, soil pH, organic carbon (OC), salinity, soil texture and cation exchange capacity (CEC), which are essential input factors for crop cultivation.

Climatic variables of daily rainfall and maximum and mean temperature were obtained for Mtibwa Sugar estate for thirty years between 1981 and 2010 from AgMIP (2014). Additional daily rainfall and minimum and maximum temperatures for land units without weather gauges were simulated using NASA POWER (Zhang et al., 2014). Also supplemental average rainfall data were obtained from the Wami-Ruvu Water Basin Office, Morogoro.

Twenty-seven soil samples from randomly selected villages were collected using an auger for soil physico-chemical analysis of the following parameters: soil texture, soil pH, organic carbon (%), salinity or EC (μScm^{-1}), cation exchange capacity (CEC), total nitrogen, available phosphorous, exchangeable bases and trace elements such as copper (Cu) Manganese (Mn), Zinc (Zn) and Iron (Fe). These soil characteristics were matched with the interpretation ratings for soil chemical characteristics (Table 4; Hunting, 1976 cited in Teka et al., 2010).

Table 4: Interpretation ratings for chemical soil characteristics

Soil variable	Very low	Low	Medium	High	Very high
EC (dS/m)	0 - 2	2 – 4	4 - 8	8 - 16	> 16
CEC (cmol(+)/kg	0 - 3	3 – 7	7 - 15	15 - 30	>30
Ntot (g/100g)	0 – 0.1	0.1 – 0.2	0.2 – 0.3	0.3 – 0.4	> 0.4
OC (g/100g)	0 – 0.6	0.6 – 1.2	1.2 – 3.0	3 – 8.7	> 8.7
pH (H2O)	5 - 6 Moderately acid	6 – 7 Slightly acid	7 - 8 Slightly alkaline	8 - 9 Moderately alkaline	9 – 10 Strongly alkaline
P available (g/100g)	0 – 0.4	0.4 – 1.3	1.3 – 2.6	2.6 – 5.3	> 5.3

Source: Hunting (1976) cited in Teka et al. (2010)

Crop requirements with respect to biophysical variables were obtained from literature (FAO, 1968; Alvim and Kozlowski, 1997; Smith and Hamel, 1999), key informants interview and expert knowledge as presented in Table 5.

Table 5: Crop biophysical requirements for selected tropical crops

SN	Crop	Rainfall (mm)	Temperature (C°)	Soil pH	Organic carbon (OC) (%)	Electrical conductivity (EC) dS/m	Cation Exchange Capacity (CEC)	Surface Texture	Drainage	Effective depth (cm)	Slope (%)
1	Maize	>600	15-35	5.8-6.8	2.0-20	0-2	20-40	Balanced	Well	>120	<10
2	Rice (irrigated)	>900	25-31	3.5-5.3	0.2-21	<10	2.12-11.4	Clay	Poor	>50	<2
3	Beans	1000-1500	15-20	5.5-6.0	2.0-20	<2	12.0-40.0	Balanced	Well	>50	<10
4	Cowpea	600-1500	15-32	4.5-7.5	>1	<2	12.0-40.0	Balanced	Well	>50	<10
5	Banana	1200-2500	19-28	5.5-6.5	3.0-20	<2	20-40	Balanced	Well	>150	<10
6	Mango	800-1000	15-30	5.5-7.5	3.0-20	<2	12.0-40.0	Balanced	Well	>300	<5
7	Citrus	800-1000	25-35	6.0-6.5	3.0-20	<1.8	12.0-40.0	Sand-loam	Well	>150	<15
8	Avocado	1200-2500	19-28	5.5-7.5	3.0-20	<1.5	20-40	Balanced	Well	>300	<10
9	Cocoa	1250-3000	19-31	4.5-7.0	3.0-20	<1.5	20-40	Balanced	Well	>150	<15
10	Teak	1250-3000	15-37	6.5-7.5	3.0-20	<1.5	20-40	Balanced	Well	>300	<20
11	Cassava	800-1500	25-35	4.2-8.0	>1.0	<1.5	12.0-40.0	Sand-loam	Well	>100	<20
12	Tomato	600-1500	18-28	5 -7.5	2.0-20	<1.5	20-40	Balanced	Well	>100	<10
13	Sesame	650-900	15-30	5.5-7.5	>1	<1.5	2.12-11.4	Balanced	Well	>50	<10
14	Sunflower	600-1500	17-32	5.5-7.5	3.0-20	<1.5	20-40	Balanced	Well	>150	<10
15	*Grevillea* sp	700-2400	17-25	4.5-7.5	3.0-21	<1.6	20-40	Balanced	Well	>250	<20
16	Cardamom	1500-3000	10.0-35	4.5-5.8	3.0-20.0	<1	15-40	Sand Clay	Well	>75	<20

Following the procedure by van Diepen et al. (1991), selected biophysical variables were classified for favouring agricultural activities at each sampled site. Since one biophysical variable does not suffice for evaluation of land unit suitability for agricultural production, a combination of properties determines the suitability instead (van Diepen et al., 1991). Therefore, biophysical variables/crop requirements combination was identified based on framework provided by Sys et al. (1991). In this framework, the most limiting factor would determine the suitability of a crop type for a given mapping unit.

Four suitability indices namely S1 (highly suitable), S2 (suitable) S3 (marginally suitable) and N (unsuitable) (FAO, 1984) were adopted. Highly suitable area for particular crops/crop combinations correspond to when all factors are favourable for optimal production of a particular crops/crop combinations, which entails a situation without biophysical (climate, slope, soil chemical reaction, soil textural class) limitation to growth and yield of a particular crops/crop combinations. The S2 indicates areas with few limitations that can be corrected at cost effective and produce optimum growth and yield. The S3 are those areas with more limitations and require too much inputs/resources to make them productive for particular crops/crop combinations.

Indigenous knowledge, in conjunction with expert knowledge was also employed to make judgement about suitability of mapping unit for any crop. For instance, crop yields reported by farmers and management practices were important in understanding the mapping unit's suitability for a certain crop.

The tabular results of land mapping unit suitability for all 16 crops (in excel sheet) were linked to the land mapping unit map using spatial join in ARCGIS 9.3. Various spatial analyses were carried out in ARCGIS 9.3 and Arcview 3.3 software to generated final land suitability maps for each crop. The final maps have been overlaid with project village boundaries, rivers, major roads, proposed village forest reserves, and buffer zones for rivers and proposed village forest reserves. All maps and the GIS database (shape-files) generated have been registered to UTM coordinate/projection and WGS 84 datum/spheroid. The final JPEG Maps have been produced in A3 paper size on landscape.

3.3 Social economic study

3.3.1 Selection of participants of focus group discussions and group interviews

Village representatives were purposively selected across all sub-villages in Bwage, Digoma, Mndela and Kinda villages with the help of respective village leaders. These villages represented dry low land areas, humid low land areas, leeward sub-humid windward humid highland areas, correspondingly. The participants were selected based on the criteria of having lived in the village for more than five consecutive years and social interactive behaviour. Groups were mixed (men and women) and consisted of 8 – 12 people. There was no cash payment provided to the interviewees except soft drinks and bites. In each village, the village representatives were split into two sub-groups of which one participated in wealth ranking (sub-section 3.3.2), and the other in focus group discussion (sub-section 3.3.3) and enterprise budgeting (sub-section 3.3.4).

3.3.2 Wealth ranking and selection of households

For each selected village, participatory wealth ranking was conducted to establish poverty profiles based on people's own perceptions of their situation. Four people from each sub-village were selected to participate in participatory wealth ranking. These individuals were selected with the help of sub-village and village leaders. For each village i.e. Mndela, Kinda, Digoma and Bwage, the selected individuals were engaged in focus group discussion (FGD) sessions to identify and agree on criteria and indicators for each wealth category. Four wealth categories were identified as described by Ravnborg (2003) were identified i.e. poorest, poor, less poor and non-poor. Thereafter, participants were split into sub-village specific groups where they were facilitated to group each household from the sub-village household list into respective wealth categories based on the criteria and indicators developed in FGD. The list of households grouped by wealth categories were then used as sampling frame for stratified random sampling.

Stratified random sampling in proportion to the size of the wealth categories was applied to select sample households. Whenever possible the minimum number of households for each category was five, except in cases where some wealth categories had fewer than five households or non-turn up of the households. The number of households sampled in each wealth category and sampling intensity for each baseline study village is shown in Table 6.

Table 6: Characteristics of sampled households and sampling intensities at Bwage, Digoma, Kinda and Mndela village within South Nguru Mountains Landscape, Tanzania

Village	Total households	Wealth categories					Sampling intensity (%)
		Non-poor	Less-poor	Poor	Poorest	Total	
Bwage	364	4*	8	13	9	34	9
Digoma	454	6	6	20	7	39	9
Kinda	326	2*	1	19	12	34	10
Mndela	263	1*	2	19	11	33	13
All villages	**1,407**	**13**	**17**	**71**	**39**	**140**	**10**

*These wealth categories had household number less than 5 because the only prospective respondents could not be traced for the entire data collection period

Sample size ranged from 33 to 39 in Kinda and Digoma villages, respectively. This gave a total number of households sampled of 140; and sampling intensity ranging from 9% in Digoma and Bwage village to 13% in Mndela village. The average sampling intensity for all villages was 10% (Table 6).

3.3.3 Focus group discussions and household surveys

Focus group discussions (FDGs) were conducted in each village to collect qualitative data on the social, economic and institutional context of people's lives and changing livelihood scenarios at community. The FDGs were facilitated through participatory rural appraisal (PRA) tools. The focus was on value chain governance (Annex 3), and participatory problem analysis with respect to threats on forest, water and soil resources. Household surveys were used to collect quantitative data using a household questionnaire covering both closed and open ended questions (Annex 4).

3.3.4. Enterprise budgeting

Ideally, cost and benefit valuation is determined based on well documented time series farm records of costs and benefits for farming activities rather than long memory recall method (Franzel, 2004; Mohan, 2004; Ajayi et al., 2009). However, such approach requires time series monitoring of a representative sample of farmers engaged in researcher-designed farmer-managed trials (Franzel, 2004). In the context of the present study, resources (time and finance) constrained the possibilities for both time series monitoring of on-farm trials and there was no possibility for assessment of farmers at different stages of implementation of different cropping systems to mimic time series situation. Thus, the study adopted enterprise budgeting through group interviews (Bullock et al., 2011). The enterprise budgeting consisted three main components namely capital investment or fixed costs, operating expenses or variable costs, and revenue (Godsey, 2008).

Enterprise budgeting sessions were facilitated through group interviews, which focused on variable costs per acre categorized as tradable inputs and labour. Tradable inputs refer to seeds, planting materials and inputs. Labour was further disaggregated into land preparation, planting, tending operations such as weeding/slashing, and harvesting of each crop. Thereafter, gross benefit was calculated by multiplying yield of each crop by the average farm-gate price and validated with the participants before the end each interview session. Separate informal interviews were subsequently organized with Mkindo Water User Association representatives from each of the surveyed villages in order to crosscheck information collected from the group interviews.

3.3.5 Socio-economic data analyses

3.3.5.1 Focus group discussions and household questionnaire

Data from FGDs were summarized around themes during discussions with community members in each village. The purpose was to identify commonalities and disparities among different people, and where necessary trying to understand the reasons for any disparity. Questionnaire data were analysed using a Statistical Package for Social Science (SPSS) Version 16.0 to provide descriptive statistics including means, percentages, frequencies, and cross tabulation.

3.3.5.2 Enterprise budgeting

a) Cost valuation

Fixed costs were estimated per acre assuming that an acre requires two hand hoe, two bush knife and two axes that last for five years. The costing of farm implements was based on prevailing local market 2014/2015 prices at Madizini town for Bwage, Digoma and Mndela villages; and local market at Mvomero town for Kinda village (Table 7). Variable costs included labour for land preparation, planting, weeding, tree thinning, crop/tree harvesting, and/or, transportation from farms to home or to the market; and inputs i.e. seeds/planting materials, fertilizers and insecticides. Similar to farm implements, inputs were valuated based on prevailing prices at the local markets (Table 7). For simplicity, the value of land was considered to be among the variable costs estimated based on prevailing local arrangements for hiring land. The cost of labour was estimated in absolute monetary values based on actual practice in the South Nguru Mountains Landscape where labour for each of different farming activities are paid on the basis of per unit of measure (e.g. cost of cultivation per acre, cost of transporting one sack of maize, etcetera) but not labour-days.

Levels of inputs and yields per care obtained from the group interviews represented the costs and benefits from the current unimproved cropping systems. These provided the stepping stone for consultants to work out costs and benefits for the hypothetical improved cropping system options for different crops/crop combinations based on judicious review of secondary data resources.

Table 7: Costs for inputs, labour and farming operations in the South Nguru Mountains Landscape in Morogoro, Tanzania

Variable	Cost per acre (TShs)				Source of information
	Bwage	Digoma	Mndela	Kinda	
Farm implements*	18000	18000	18000	17000	2014/2015 market prices
Hiring farmland	40,000	40,000	30,000	35,000	Farmers' estimates
Land preparation	40,000	40,000	35,000	45,000	Farmers' estimates
Nitrogen fertilizers**	120,000	120,000	130,000	200,000	2014/2015 market prices
Phosphate fertilizers**	80,000	80,000	80,000	80,000	2014/2015 market prices
Fertilizer transportation	10,000	10,000	20,000	30,000	Transport operators' estimate
Fertilizer application	20,000	20,000	30,000	30,000	Farmer's estimates
Weeding	65,000	90,000	70,000	50,000	Farmers' estimates
Slashing in woodlot	40,000	60,000	40,000	30,000	Farmers' estimates
Pesticides***	11,000	11,000	11,000	11,000	2014/2015 market prices
Harvesting	50,000	52,000	80,000	45,000	Farmers' estimates
Transportation from farm to home	80,000	124,000	130,000	150,000	Farmers' estimates

*Farm implements include hand hoe, matchet and axe; **Research based recommended fertilizer rate is 2 bags of 50 kg per acre for nitrogen and 1 bag of 50 kg per acre for phosphorus.
***Karate (sold at 5,000) and thionex (sold at 6,000) used for horticultural crops only
****Used for all crops, except for cocoyam, cassava, trees and fruits sold at the farm site

b) Crop yield estimates

Dynamics in responses of crop yields from different hypothetical improved cropping options in comparison to typical continuous cropping system estimated from relevant peer reviewed publications is presented in Table 8; whereas current yields in continuous cropping for different crops were obtained from group interviews.

Table 8: Response ratios for relevant crop production systems relative to the current continuous cropping system

Crop	The peak response ratio (%) for cropping system relative to continuous cropping system					
	Fertilizer application	Reference	Agroforestry	Reference	Fertilizer and agroforestry combined	Reference
Bean	160%	Kanonge et al. 2009	117%	Somarriba and Beer, 2011	NA	-
Maize	1.89	Kwesiga et al. 1999	180%	Kwesiga et al. 1999	343%	Kimaro, 2009
Pigeon peas	150%	Kanonge et al. 2009	140%	-	NA	-
Rice	138%	Szotte et al 1991	NA	-	NA	-
Sesame	190%	El-Nakhlaw and Shaheen, 2009	NA	-	NA	-
Sunflower	200%	Zubillaga et al. 2002	NA	-	NA	-
Tomatoes	100%	Information from farmers	NA	-	NA	-
Maize/pigeon peas	163%	Kimaro, 2009	NA	-	NA	-

It was noted that the response variables and experimental designs differed considerably among publications. In such a context, the analysis of change relative to the control or response ratio is more meaningful than standardized absolute differences between means (Elser et al., 2007). Thus, we adopted response ratio (Hedges et al., 1999) to gauge crop yield responses of continuous cropping system with respect to various hypothetical improved cropping systems. The response ratio is the most reliable effect metric in ecological meta-analysis because it quantifies the proportionate change that result from an experimental manipulation.

Furthermore, in the agroforestry cropping system proposed in the present study, the period prior competitive effects of the trees on intercropped crops is extended from three years predicted by Ong et al. (2000) to five years. This is possible by adopting wide initial tree spacing of 4 m x 4 m (Muthuri et al., 2005) coupled with integration with less competitive soil improving shrubs i.e. *Tephrosia vogelii* or *Tithonia diversifolia or Lablab purpureus or Crotolaria ochroleuca;* to ensure production of adequate green manure foliage for soil nutrient cycling

(Sanchez and Jama, 2002). With the new innovative agroforestry cropping system, yield of cereal crops reaches its peak at the second year and maintained up to the third year before it decline by 10% and 20% of the maximum yield in the fourth and fifth year correspondingly.

It is worth noting that, for the leeward sub-humid highland areas (represented by Kinda village), humid windward highland areas (represented by Mndela village) and lowland humid areas (represented by Digoma village); the period from the sixth to tenth year of the agroforestry system cereal crops are replaced by shade-tolerant taro palagi (*Xanthosoma sagittifolium*) in the foothills or (*Colocasia esculenta*) in wet valley bottoms (Valenzuela et al., 1991; Newman et al., 1997; De Clerck et al., 2000). At this stage, the cocoyam benefits from the accumulated organic matter and improved microclimate that mimic conditions found in selectively logged natural forests where cocoyam is grown in the present unsustainable cropping system in the South Nguru Mountains landscape. At the end of the tenth year, the tree component of agroforestry cropping system is harvested to provide building poles and firewood and the cycle begins again with coppice regeneration, integrated with cereal crops and less competitive soil improving shrubs.

c) Valuation of benefits

Benefits for crops from different cropping systems were determined based on yields per acre and prevailing average farm-gate prices from the enterprise budgeting group interview sessions. Determination of benefits for fruits i.e. Avocado, oranges and mangoes was based on the fact that the fruits reach their production peak starting at 6 years of planting and continues with that level of production up to 10 -12 years before yields start to decline (Rasul and Thapa, 2006). Therefore, the cost-benefit analyses of fruits adopted a 10-year time horizon. By the same token, economic analyses for agroforestry, and *Tectona grandis* and *Grevillea robusta* woodlots cropping systems were based on 10, 20 and 25 time horizons, respectively.

3.3.5.3 Financial evaluation criteria of the different crops/crop combinations

The **profitability** of different production possibilities for various crops/crop combinations were assessed by comparing it with their counterparts produced under continuous cultivation, because that was the dominant cultivation system at the time of assessment. Evaluation of the financial efficiency of the respective crops/crop combinations was performed using the Financial Cost-Benefit Analysis (FCBA) methods for each sample village representing respective agro-ecological zone (Enters, 1998). The analysis expressed future benefits and costs of different crops/crop combinations per acre in present value using interest rate of 6%, which has been defined as medium discount rate factor in Tanzania (Tenge and Hella, 2005). The medium interest rate was applied as an average for different time preferences among different wealth categories. The study adopted net present value (NPV) as the ultimate efficient FCBA criteria, which was computed based on equations 1.

$$NPV = (B_0 - C_0) + \left(\frac{B_1 - C_1}{(1+r)}\right) + \left(\frac{B_2 - C_2}{(1+r)^2}\right) + \cdots + \left(\frac{B_n - C_n}{(1+r)^n}\right) \qquad (1)$$

Where B_0, B_1, B_2...B_n are streams of benefits in monetary terms

C_0, C_1, C_2...C_n are streams of costs in monetary terms

r is discount rate

The choice of NPV as a financial analysis criterion is justified by the fact that it has been frequently reported to coincide with farmers decisions on adoption of particular land use type (Kibria and Saha, 2011).

4. RESULTS AND DISCUSSION

4.1. Biophysical characterization of the area

The biophysical characteristics of an area are critical in determining its suitability to agriculture, conservation and management options. The biophysical characteristics include geology, soils, hydrology and vegetation. The study area can be broadly categorized into four zones based on the altitude and rainfall. These categories are: the highland with high altitude or mountainous and lowland zones. In the highland zones there are some mosaics of areas which are dry while most of the areas are humid. The distribution of the project villages in each zone is presented in Table 9.

Table 9: Preliminary description of biophysical features of the South Nguru Mountains in Mvomero district, Tanzania

Physiography/Altitude	Climate	Villages
Highland	Dry	Mziha, Pemba (Nyakome), Masimba (Manyanga), Bwage, Matale, Makuyu
Highland	Humid	Dihombo, Misufini, Digalama, Hembeti, Mndela, Medina, Msolokelo (Gombero), Maskati (Dibago), Kisimaguru, Kwelikwiji, Gonja, Pemba, Kanga, Mafutaha, Dihinda, Ubiri, Mkindo?,Komtonga, Mlaguzi, Mbogo, Kigugu, Digoma, Mvomero, Semwali, Mhonda
Lowland	Dry	Mziha, Pemba (Kombe), Msolokelo (msolokelo), Bwage Makuyu, Masimba, Matale
Lowland	Humid	Dihombo, Digoma, Kigugu, Hembeti, Kwadoli, Mkindo, Komtonga, Msufini, Mbogo, Kanga, Dihinda, Difinga, Bwage, Kigugu, Mvomero

In each of the broad biophysical categories, landscape level characterization revealed that the area consisted of diverse landscape characteristics. The landscape characteristics, which also form the major eight mapping units includes the broad valleys 2 (B2), broad valleys 2 (D03), flood plains (K05), foothills and ridges (D04), moderate slope mountains (K09), steep slopes mountains (K08), and steep mountains (M06) and M07 (Figure 6). The broad valleys are located in parts of Digoma and Kwadoli represented by mapping unit D03 (Figure 6). Other broad valleys covering small percent of the area are found mostly along the river basin in Dihinda, Kanga, Mziha, Bwage, Difinga, Msolokelo, Mndela, Kisimagulu and Mvomero are under the B01 mapping unit (Figure 6). The flat to undulating plains (B02 mapping unit) extends widely in the north-east of the study area in Dihinda, Kanga, Bwage, and Mziha villages. Another importantlandscape feature designated as K05 mapping unit is the flood plain, which extends along the Wami river networks of the study area from Msufini north-eastwards to Komtonga, covering Hembeti, Digombo, Mkindo, Kigugu and Mbogo villages. Foot hills and ridges also form an important landscape feature of South Nguru Mountains Landscape which are found in small portion adjacent to the villages in flood plains, and found in large portion in the highlands covering Difinga, Msolokelo, Masimba, Pemba, Ndole, Matale, Makuyu, Mvomero and some parts of Msufini, Hembeti and Semwali represented by D4 mapping unit. The steep mountains (K08 mapping unit) and moderate slope mountains (K09) extends widely in the western side of the study area extending from south-west to north-west covering some parts of some parts of Makuyu, Mvomero, Matale, Semwali, Ndole, and Difinga. The whole of Kinda, Dibago, Maskati and Gonja, and large part of Masimba and Pemba is also characterised to have steep and moderate slop mountains (Figure 6).

4.1.1. Soil physical and chemical properties of the major landscape features

Landscape characteristics have an impact on soil characteristics due to the influence of relief, climate and vegetation soil forming factors. Thus, the soil physical and chemical properties that plays significant role in agricultural production were assessed in each representative mapping units (Table 10).

Table 10: Soil physical properties of the major landscape units of South Nguru Mountains Landscape in Mvomero district, Tanzania

Mapping Unit	Villages	Representative Site	Slope (%)	Soil depth (cm)	Particle size %			Textural class
					Sand	Silt	Clay	
B01 Flat undulating plains (Flat to Undulating)	Bwage	Kichangani	1 to 4	0-15	43	12	45	C
				15-30	47	14	39	C
B02 Broad Valley2 (Broad valley in dry area)	Bwage	Kigugu	4	0-15	13	6	81	SL
				15-30	11	4	85	C
D03 Broad Valley (Broad valley in wet area)	Digoma	Makuyu	< 5	0-15	43	24	33	C
				15 -30	45	22	33	C
D04 Foothills and ridges (Foot ridges/hills in wet area)	Digoma	Makuyu	< 10	0-15	65	6	29	C
				15-30	71	14	15	C
K05 Flood plains (Flood plain)	Kigugu	Bogolwa	flat	0-15	41	12	47	**SC**
				15-30	49	10	41	C
K08 Steep slope mountains (Steep slope mountain in dry area)	Kinda	Mgombelwa	30 to 39	0-15	43	12	45	C
				15-30	43	12	45	C
K09 Moderate slope mountains (Moderate slope mountain in dry area)	Kinda	Kwedigamba	9 to 10	0-15	37	12	51	**SC**
				15-30	43	12	45	C
M6 Steep mountains (Steep slope mountain in wet area)	Mndela	BigwaJuu	40 to 67	0-15	39	18	43	**CL**
				15-30	43	16	41	C
M7 Steep mountains (Moderate slope mountain in wet area)	Mndela	Digugu	10 to 24	0-15	31	20	49	SCL
				15-30	43	14	43	C
DRF Foot ridges/hills in dry area	Digoma	Makuyu	< 10	0-15	65	6	29	C
				15-30	71	14	15	C

Key: Textural class: C – Clay; CL – Clay loam; SC – Sandy clay; SL – Sandy loam.

4.1.2. Chemical properties of the surface soils of the selected areas of Nguru

Soil chemical properties are critical in determining appropriate conditions for plant growth and yield by regulating both the chemical forms of nutrients to be absorbed by plant and the content of those nutrients. The soil pH of the top soil of the selected areas of the South Nguru Mountains ranges from 5.31 to 6.40 while electrical conductivity (EC) ranges from 0.041 to 0.264 dS/m (Table 11). The soil pH from D03 and K08 of the study areas are categorized as very strong acid soils (pH<5.5) (McFarland et al., 2001), while soil from the foot hills D04 and flood plain K05 are slightly acid soils (pH>6 and <6.5). The rest of the soils (about 59%) are moderately acid (pH between 5.5 and 6.0). Therefore most of the soil pH of the study area do not limit growth and yield of most agricultural crops. However, soils from D03 and K08 are likely to affect growth of many crops and liming or use of Minjingu phosphate as source of P is required. The EC of all soils is low, showing no potential salt accumulation problem, but also indicates generally low availability of dissolved nutrients in these soils.

The total nitrogen provides overall content of different forms of N [inorganic (NO_3 and NH_4) and organic N in the soil]. The total N of most (88%) of soils surveyed ranges from medium (between 0.13 and 0.23%) to high (> 0.23) (Landon, 1991), with exception of soil from B02 Broad valley, where the total N is low. Phosphorus is low (<7 mgP/kg) according to Amuri et al. (2014) in all soils studied, except in the flood plains denoted by K05. These results show that phosphorus is the most limiting nutrient for crop production in these areas. The high soil P in K05 flood plain is due to use of P fertilizers, which is likely in rice growing areas. The exchangeable K in the South Nguru representative areas ranges from 0.05 to 0.73 cmolc/kg (Table 11), of which 67% of the soils had low exchangeable K (<0.40 cmolc/kg) while the remaining 33% had medium exchangeable K (between 0.4 to 1.2 cmolc/kg) as per ratings by Landon (1991). Therefore, based on soil test results availability of P and K for adequate production of most crops will be low and require addition of these nutrients in form of fertilizers (organic and inorganic).

Table 11: Chemical properties and macronutrient content of soils representing the major landscape units of South Nguru Mountains Landscape in Mvomero district, Tanzania

Mapping Unit	Village	Rep. Site	Soil depth (cm)	pH (H2O)	EC (dS/m)	TN (%)	Avail. P (mg/kg)	Exch. K (cmolc/kg)
B01 Flat undulating plains (Flat to Undulating)	Bwage	Kichangani	0-15	6.04	0.106L	0.20 M	2.62 VL	0.39 L
			15-30	6.38	0.0368	0.1037	0.78	0.20
B02 Broad Valley2 (Broad valley in dry area)	Bwage	Kigugu	0-15	5.95	0.041L	0.08 L	1.49 VL	0.05 VL
			15-30	6.05	0.0368	0.06	0.99	0.04
D03 Broad Valley (Broad valley in wet area)	Digoma	Makuyu	0-15	5.36 L	0.124L	0.37 H	1.79 VL	0.22 L
			15-30	5.08	0.0814	0.37	1.24	0.13
D04 Foothills and ridges (Foot ridges/hills in wet area)	Digoma	Makuyu	0-15	6.34	0.154L	0.17 M	0.83 VL	0.73 M
			15-30	6.08	0.1391	0.16	0.28	0.53
K05 Flood plains (Flood plain)	Kigugu	Bogolwa	0-15	6.40	0.264L	0.17 M	15.09 H	0.19 L
			15-30	6.08	0.488	0.13	2.62	0.17
K08 Steep slope mountains (Steep slope mountain in dry area)	Kinda	Mgombelwa	0-15	5.31 L	0.071 L	0.47 H	0.95 VL	0.19L
			15-30	5.30	0.0485	0.24	1.7 VL	0.07
K09 Moderate slope mountains (Moderate slope mountain in dry area)	Kinda	Kwedigamba	0-15	5.90	0.075 L	-	4.57 L	0.45 M
			15-30	5.56	0.0497		1.74 VL	0.17
M6 Steep mountains3 (temp) (Steep slope mountain in wet area)	Mndela	BigwaJuu	0-15	5.65	0.05 L	0.29 H	2.83 VL	0.33 L
			15-30	5.15	0.0386	0.18	2.62 VL	0.20
M7 Moderate slope mountain 4 (Moderate slope mountain in wet area)	Mndela	Digugu	0-15	5.80	0.124 L	0.33	1.83 VL	0.68 M
			15-30	5.3	0.071	0.23	0.95	0.25
DRF Foot ridges/hills in dry area	Digoma	Makuyu	0-15	6.34	0.154L	0.17 M	0.83 VL	0.73 M
			15-30	6.08	0.1391	0.16	0.28	0.53

Nutrient ratings: H – high; M – medium; L – low; VL – very lowbased on categorization by Landon (1991),

4.1.3. Secondary and micronutrient content in soil of South Nguru Mountain

Soil fertility management to achieve climate smart agriculture emphasize on ensuring balanced nutrients for plant uptake. Thus, the status of secondary and micronutrients were determined. The results show that all soils of South Nguru have sufficient S (> 37 mg SO4-S/kg) to support production of many crops. The exchangeable Ca and Mg ranges from medium to high and are not expected to pose limitation to crop production. The micronutrients Cu, Mn and Fe are at sufficient levels in all mapping units surveyed (Table 9). However, Zn is low in 33% of the studied soils from the broad valley (coded as B01) steep slope mountain (coded as K08) and steep mountain (coded as M6) mapping units (Table 10). Therefore, Zn fertilization is required in the three mapping units to ensure balanced fertilization for improved productivity of crops.

Table 12: Secondary and micronutrient content of soils representing the major landscape units of South Nguru Mountains Landscape in Mvomero district, Tanzania

Mapping Unit	Village	Representative Site	Secondary nutrients			Micronutrient content (mg/kg)			
			SO4-S mg/kg	Ca (cmolc/kg)	Mg (cmolc/k)	Cu	Zn	Mn	Fe
B01 Flat undulating plains (Flat to Undulating)	Bwage	Kichangani	40.20 H	17.6 H	10.4 H	8.83 H	1.23 H	84.25 H	156.9 H
B02 Broad Valley2 (Broad valley in dry area)	Bwage	Kigugu	57.15 H	8.57 M	2.95 M	1.96 H	0.49 L	47.64 H	76.65 H
D03 Broad Valley (Broad valley in wet area)	Digoma	Makuyu	66.95 H	9.55 M	4.19 H	3.08 H	4.49 H	103.52 H	637.88 H
D04 Foothills and ridges (Foot ridges/hills in wet area)	Digoma	Makuyu	40.20 H	7.83 M	2.95 M	2.31 H	6.63 H	84.25 H	25.76 H
K05 Flood plains (Flood plain)	Kigugu	Bogolwa	51.32 H	14.72	8.59 H	3.16 H	3.23 H	45.71 H	252.05 H
K08 Steep slope mountains (Steep slope mountain in dry area)	Kinda	Mgombelwa	51.05 H	2.41 M	1.34L	4.02 H	0.27 L	38.01 H	68.262 H
K09 Moderate slope mountains (Moderate slope mountain in dry area)	Kinda	Kwedigamba	42.85 H	8.57 M	2.54M	4.02 H	2.12 H	47.64 H	52.605 H
M6 Steep mountains (Steep slope mountain in wet area)	Mndela	BigwaJuu	35.43 H	4.38 M	1.74 L	0.42 H	0.79 L	14.01 H	62.67 H
M7 Moderate slope mountain 4 (Moderate slope mountain in wet area)	Mndela	Digugu	34.37 H	8.57 M	3.24 M	2.99 H	2.41 H	86.18 H	62.67 H
DRF Foot ridges/hills in dry area	Digoma	Makuyu	40.20 H	7.83 M	2.95 M	2.31 H	6.63 H	84.25 H	25.76 H

Nutrient ratings: H – high; M – medium; L – low based on categorization by Landon (1991),

4.2. Crop profiles

4.2.1 Crop suitability maps

4.2.1.1 Maize

Generally there was no highly suitable land unit for maize with respect to natural biophysical resources availability. However, flood plains, flat to undulating landforms were found to be suitable for maize. Foot ridges/hills and moderate slopes were found to be marginally suitable whereas steep slope mountain mapping units were not suitable for maize production (Figure 7).

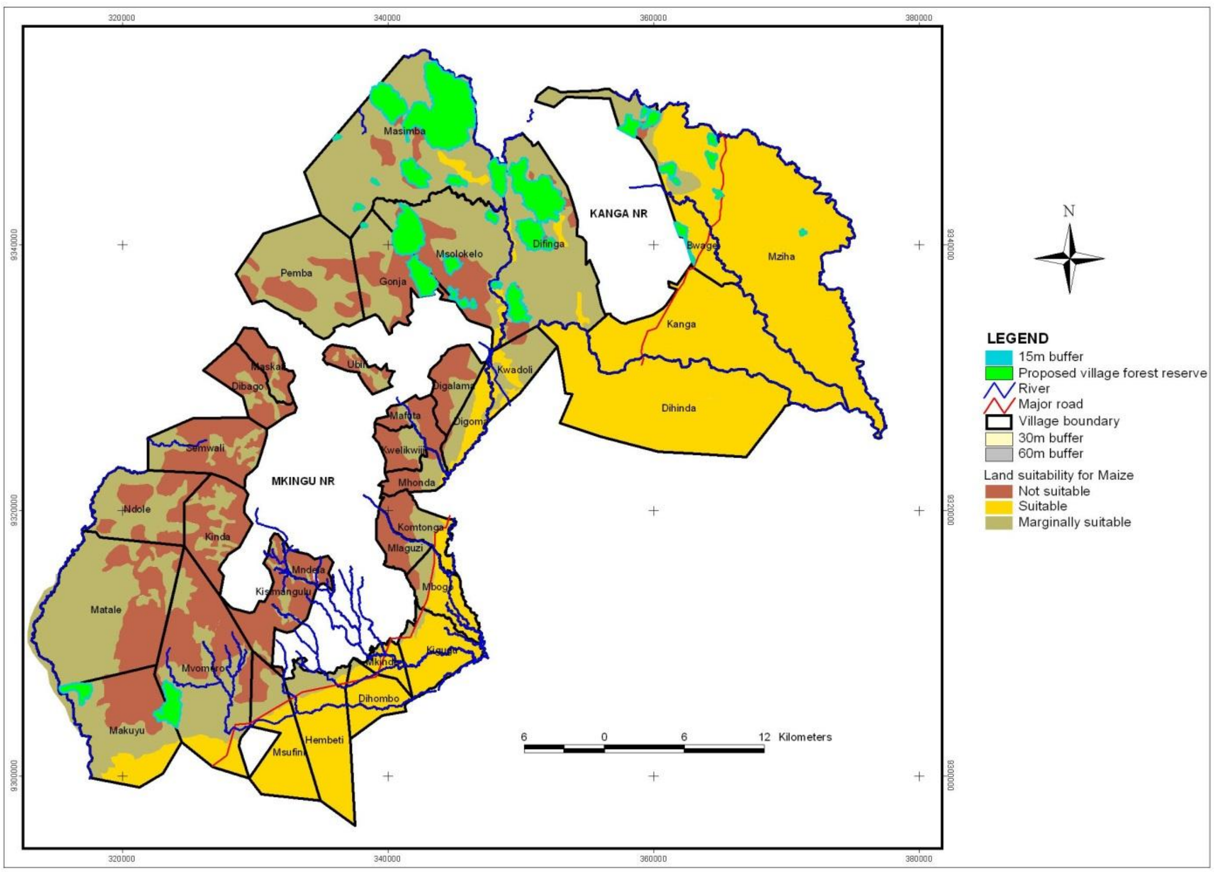


Figure 7: Map indicating land suitability levels for maize in South Nguru Mountains Landscape in Mvomero district, Tanzania

Slope, soil reaction (pH) and organic matter were the major soil variables which determine land unit suitability for maize production. Steep slopes as those found at Mndela and Kinda affects maize production due to soil erodibility, and workability. Acidic soils as those found in Digoma, Mndela and Kinda villages make these areas to become marginally suitable for maize. Low soil pH affects availability of other nutrients such as Phosphorus, Calcium, Magnesium availability while enhancing high availability of Iron, (Fe), Aluminum (Al). Fe and Al toxicity leads to severe effects on roots development, and in turn, absorption of nutrients and water. **However, maize production can be undertaken after amelioration of limiting factors. Such measures as terracing on steep slopes, liming on acidic soils of and enhancement of soil organic matter would be adequate for profitable maize production.**

4.2.1.2 Rice

Like maize, there was no land mapping unit with highly suitable land characteristics. Suitable areas are those in flood plains, flat to undulating. Marginally suitable areas are those found in broad valleys. Foot ridges/hills and mountainous areas (both moderate slope and steep slope) are unsuitable for rice production (Figure 8). Slope seems to be a major limiting factor for rice production in the study area. This has direct effect on water availability for rice crop growth. Understandably, bunds can more easily be connstructed on flat landscapes than on sloping land**.**

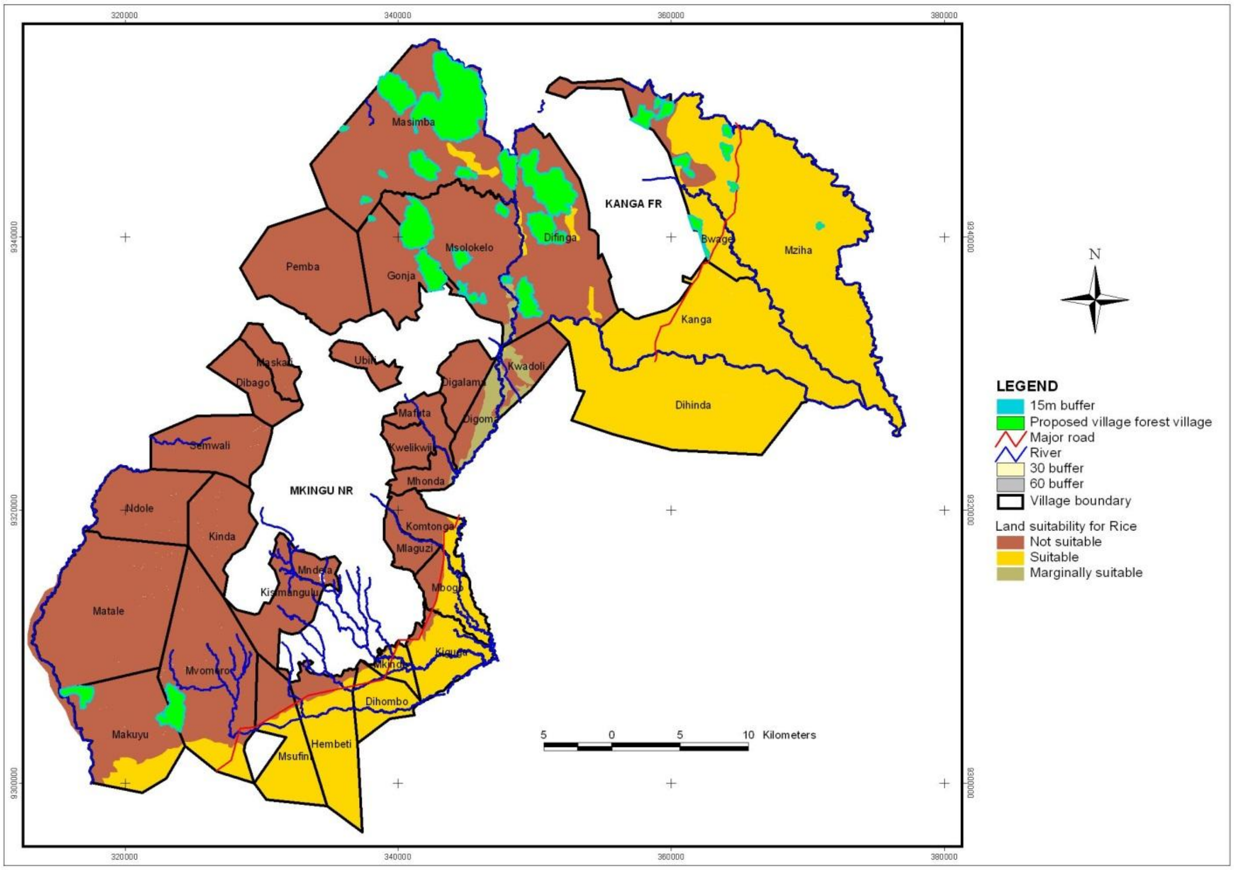


Figure 8: Map indicating land suitability levels for **rice** in South Nguru Mountains Landscape in Mvomero district, Tanzania

4.2.1.3 Banana

All land units were marginally suitable for banana production except the broad valley of dry areas and steep to very steep mountainous areas which are not suitable. Major biophysical variables limiting banana production is low rainfall in dry, broad valleys. Also, in highlands which have adequate rainfall, steep slope is the major limiting factor (Figure 9).

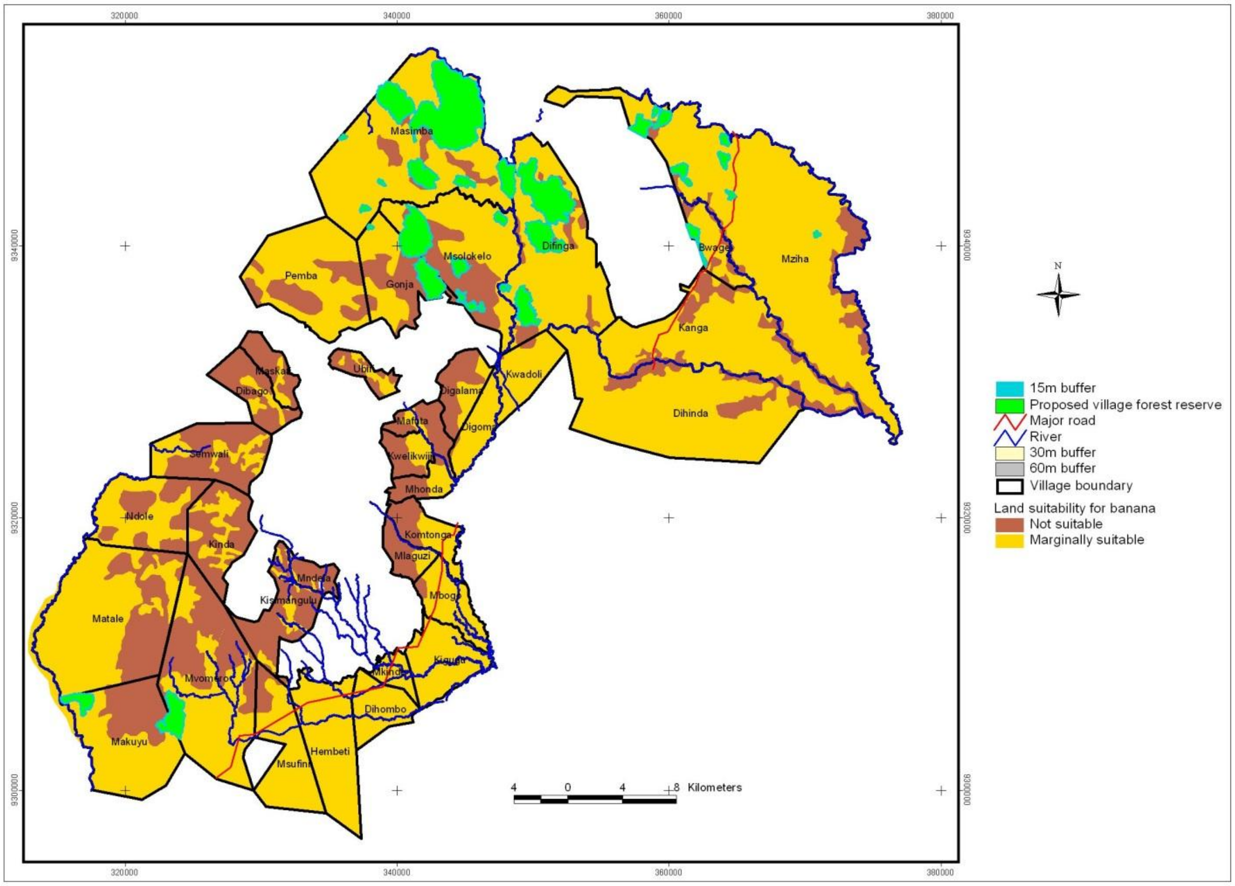


Figure 9: Map indicating land suitability levels for **Banana** in South Nguru Mountains Landscape in Mvomero district, Tanzania

4.2.1.4 Beans

Soil pH, organic matter and steep slopes were major limiting factors for beans production in the study area. Land units with acidic soils, low organic matter and steep slopes were marginally suitable or unsuitable for bean production. Most broad valleys of the dry areas and steep slopes of the mountainous land units were not suitable, whereas flat to undulating land units are suitable for beans. Flood plains as well as foot ridges/hills and gently moderate slopes were marginally suitable for beans production (Figure 10). **Soil pH amendments through liming, use of soil and water conservation measures such as terraces or contour hedges may be necessary for improved beans production in land units where these variables are most limiting.**

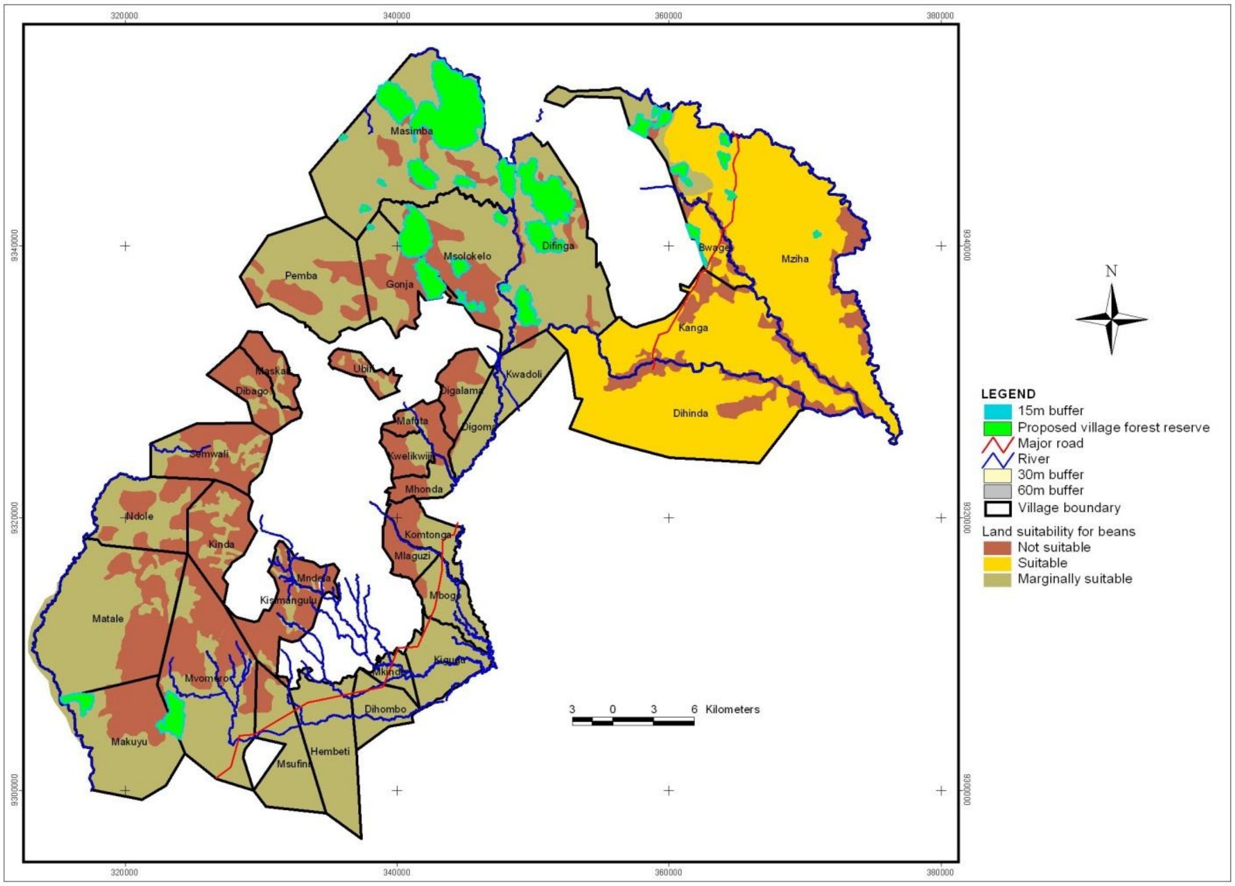


Figure 10: Map indicating land suitability levels for **Beans** in South Nguru Mountains Landscape in Mvomero district, Tanzania

Integration of these practices with AF, and/or conservation agriculture (Hobbs et al., 2008) can help to increase the required organic matter to enhance beans productivity. Regarding promotion of soil and water conservation measures in the landscape, the most practical option is to scale up terraces and pineapple contours that have been successfully established in Uluguru Mountains as reported by URT (2009; 2010). Thus, under improved and low cost land management practices the entire landscape can be easily converted to be suitable for beans production.

4.2.1.5 Cowpeas

All land units are marginally suitable except those under broad valleys of dry area, steep to very steep mountainous areas which are not suitable (Figure 11). Like beans, cowpea production is limited by soil acidity and steep slopes. Therefore, interventions to address soil acidity and steep slope may lead to enhanced cowpeas production in the project area.

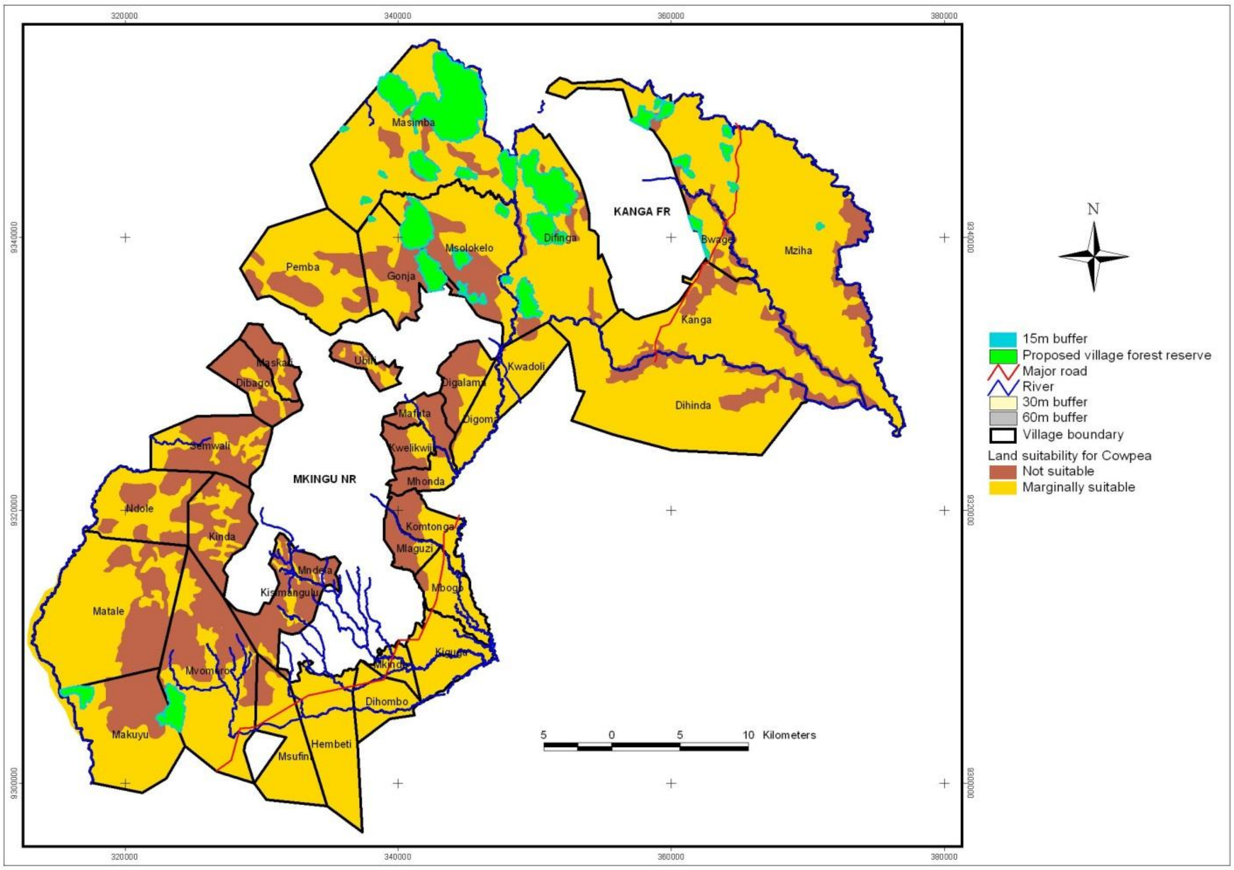


Figure 11: Map indicating land suitability levels for **cowpeas** in South Nguru Mountains Landscape in Mvomero district, Tanzania

4.2.1.6 Cassava

Flat to undulating land units are suitable whereas flood plains, foot ridges/hills and moderate slope mountains land units are marginally suitable for cassava production. Steep Slope Mountains are not suitable for cassava production (Figure 12). Major limiting factors for cassava production in the study area are mainly the slope, soil pH and soil organic matter, suggesting that with proper interventions to correct soil pH, terracing to handle the slope and addition of organic matter to the soil would enhance cassava production in the study area.

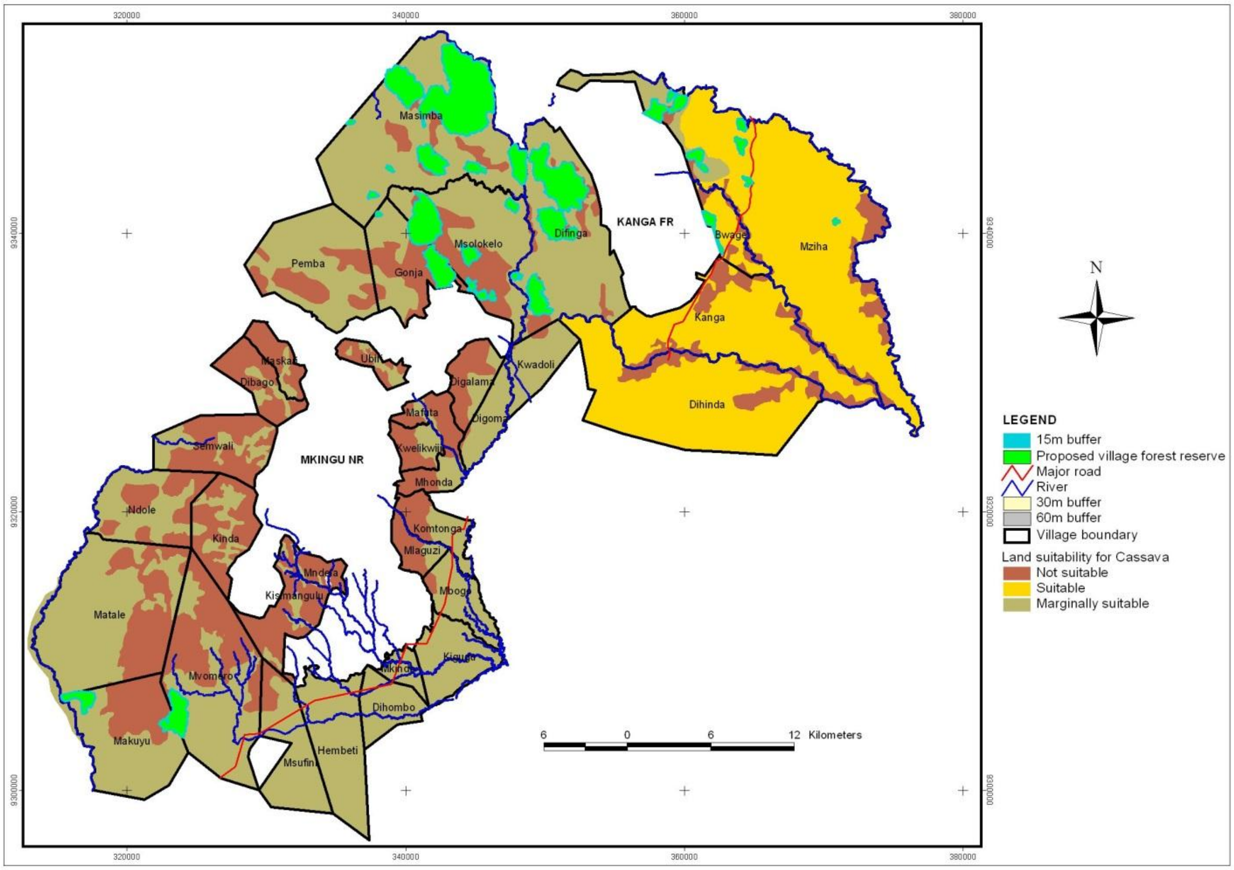


Figure 12: Map indicating land suitability levels for cassava in South Nguru Mountains Landscape in Mvomero district, Tanzania

4.2.1.7 Sunflower

Flood plains, flat to undulating land units are suitable (S2), whereas the rest of land units except steep slope mountains are marginally suitable for sunflower production. Steep slopes are not suitable (Figure 13). Slope is the main limitation to sunflower production and this is related to the fact that steep landscapes are prone to erosion and have poor water holding capacity unless terracing is undertaken.

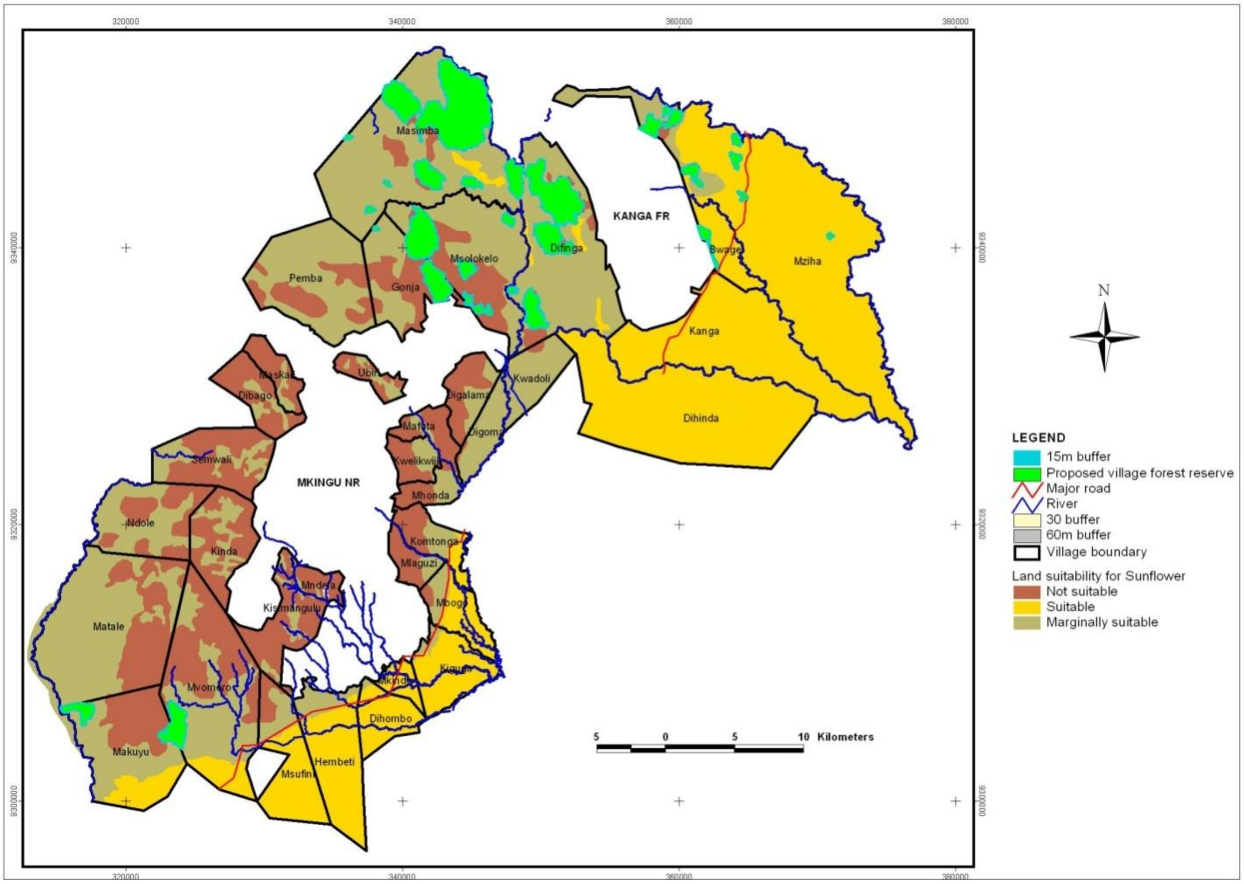


Figure 13: Map indicating land suitability levels for **sunflower** in South Nguru Mountains Landscape in Mvomero district, Tanzania

4.2.1.8 Sesame

Broad valleys of wet area and flat to undulating land units are suitable for sesame production. Flood plains, foot ridges/hills and moderate slope mountains land units are marginally suitable. On the other hand, steep slope mountains and broad valley of dry areas are not suitable (Figure 14). Generally, sesame production in the project area is limited by soil texture, organic matter content and slope of the land unit. Sandy soils do not favour sesame production due to low water and nutrient holding capacity, a factor which can be conditioned by soil organic matter. Steep slopes have problems with soil erosion as well as water and nutrient availability, thus cannot support sustainable sesame production.

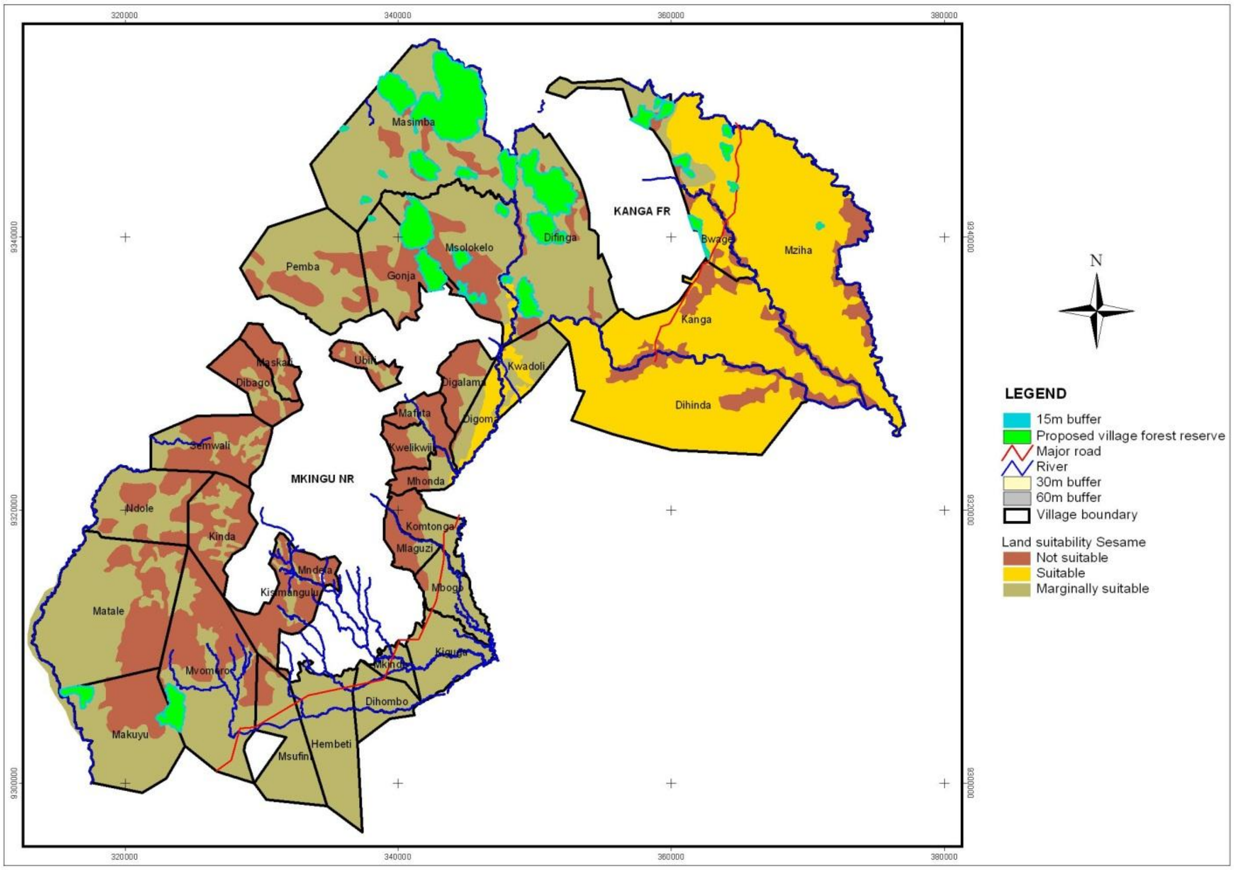


Figure 14: Map indicating land suitability levels for **sesame** in South Nguru Mountains Landscape in Mvomero district, Tanzania

4.2.1.9 Cocoa

Cocoa is a perennial, tree crop adapted to high rainfall, and warm areas. The soils have to be fairly fertile. In the project area, flood plains, flat to undulating land units are suitable for cocoa production. Foot ridges/hills and moderate slope mountains are marginally suitable whereas the steep slope mountains and broad valley of drier areas are not suitable for cocoa production (Figure 15). In the project area, such biophysical variables as soil pH, soil organic matter content and slope were the most limiting to cocoa production. Such intervention practices as liming (to raise soil pH) terracing (to check soil erosion) and application of organic matter are necessary for improved production of cocoa in the project area.

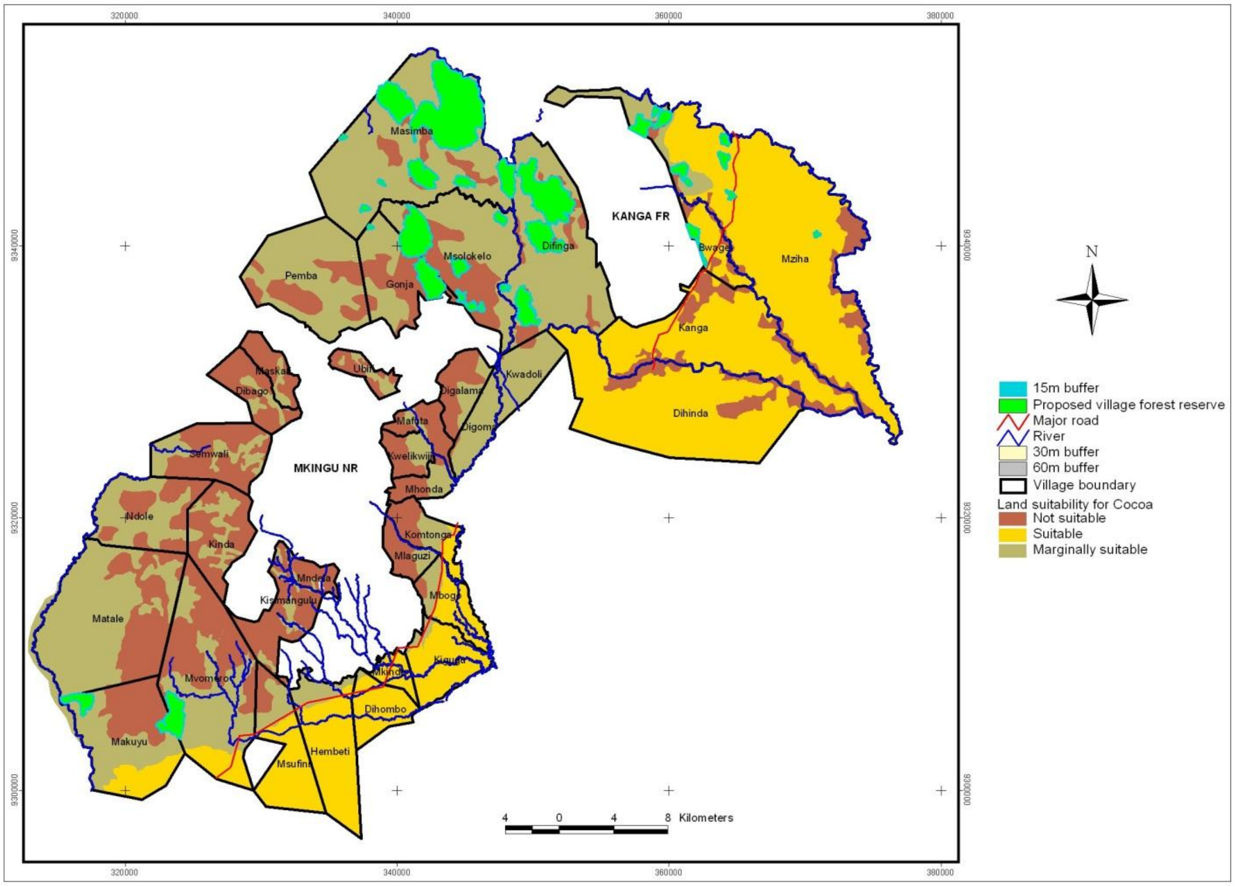


Figure 15: Map indicating land suitability levels for Cocoa in South Nguru Mountains Landscape in Mvomero district, Tanzania

4.2.1.10 Tomato

Tomato is an annual vegetable crop which requires less to moderate rainfall and fertile soils. In the project area, flat to undulating land units are suitable for the crop whereas foot ridges/hills and moderate slope mountains are marginally suitable. On the other hand, broad valleys (both wet and dry) and steep sloping land units are not suitable for tomato production (Figure 16). Mean annual rainfall amount plays role in facilitation of tomato disease development and spread, under which case high rainfall areas are not normally suitable for tomato production unless strict disease control is instituted.

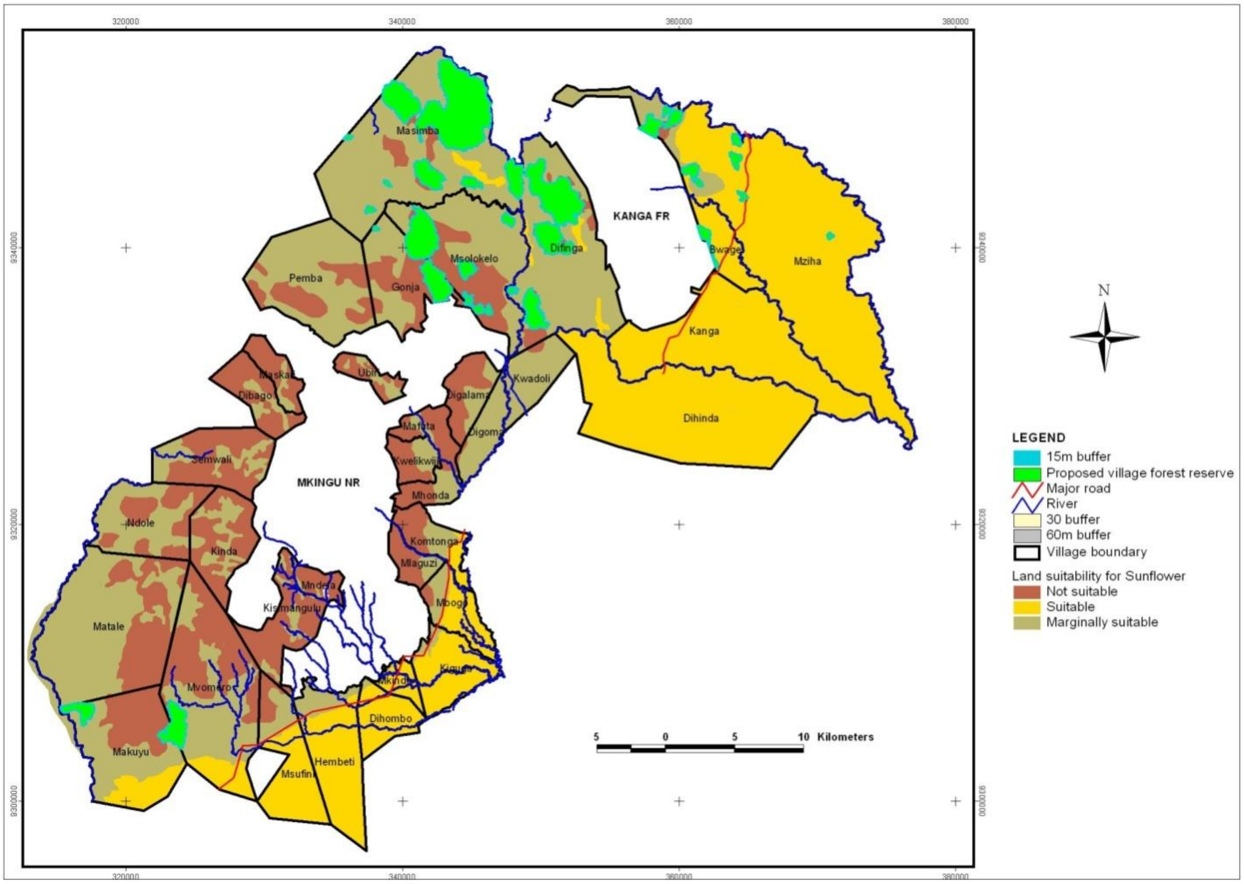


Figure 16: Map indicating land suitability levels for tomato for cassava in South Nguru Mountains Landscape in Mvomero district, Tanzania

4.2.1.11 Citrus

Citrus requires substantial amount of rainfall and good, fertile soils. In the project area, only two suitability levels –marginally suitable and not suitable are reported. Flood plains, foot ridges/hills of wet areas, moderate slope mountains and broad valley of wet area land units are marginally suitable for citrus production. The remaining land units are not suitable, according to this assessment (Figure 17). Rainfall is the major limiting variable to citrus production in most parts of the project area, suggesting that if irrigation can be afforded, then citrus production may be possible.

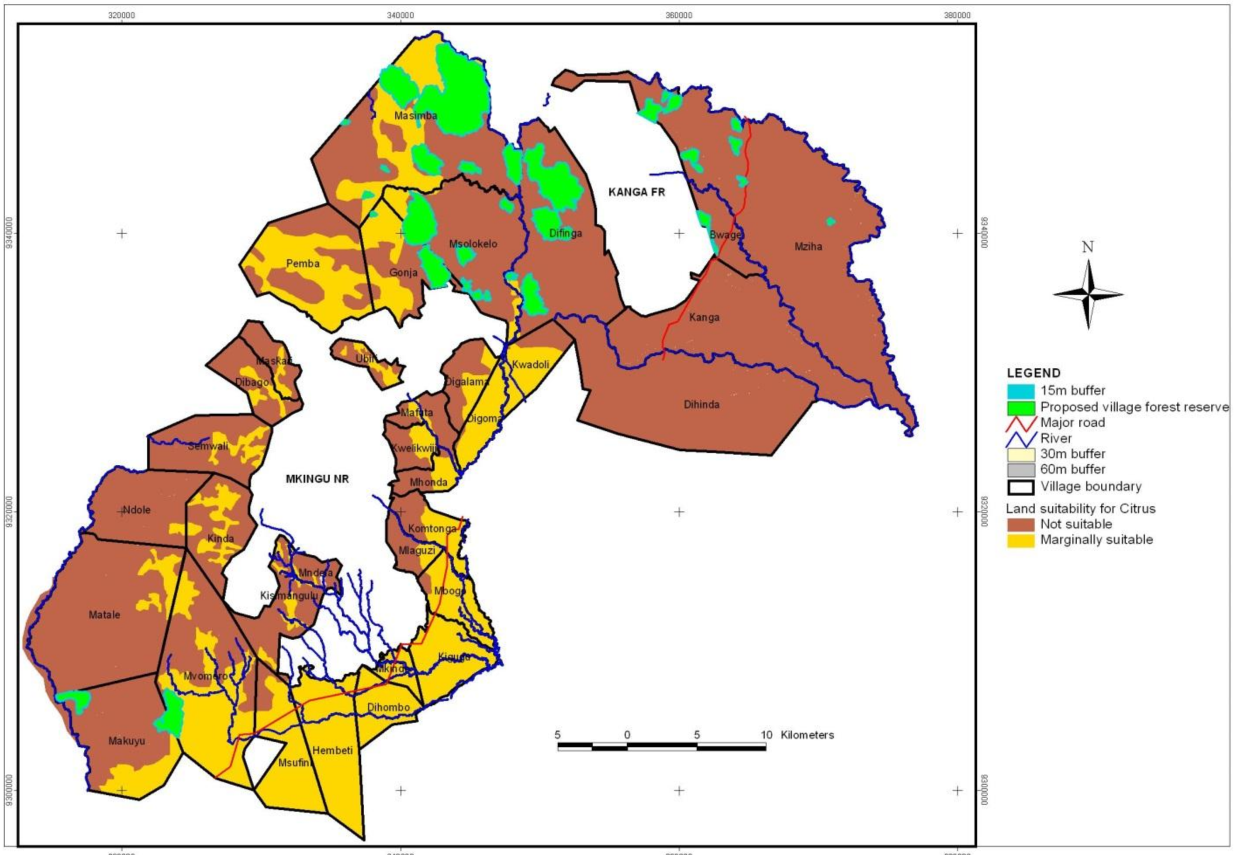


Figure 17: Map indicating land suitability levels for citrus fruits in South Nguru Mountains Landscape in Mvomero district, Tanzania

Annex 5 summarises the land suitability levels of land mapping units for each crop type.

4.2.2 Selected crop varieties characteristics and inputs needs suitable in the South Nguru Mountains Landscape

Potential yield of the variety of any crop based on its genetic ability is achieved when all growing conditions (moisture, soil physical and chemical conditions including nutrient availability), and the crop agronomic management (seed quality, plant spacing, pest control, weeding) are adequate. If any of the growing conditions and management is not adequate the crop varieties potential yield will not be attained. Another crop characteristics of importance is duration of maturity of crop variety, which is an important factor to consider in climate smart agriculture. Shorter maturing varieties tend to have more adaptive capacity to climate change impact especially drought. Therefore, given varieties of the same characteristics, short maturing varieties should be given priority. Other crop variety characteristics to consider include pest and disease resistance/tolerance, and cooking/eating/milling quality, and marketable quality. Examples of common maize and rice varieties suitable in the project area are summarized in Table 13 and 14. It should also be noted that new maize and rice varieties are released every year with more adaptive quality such as drought and disease tolerance, which needs to be considered in the project implementation.

Table 13: Characteristics of maize varieties appropriate in Eastern Agro-ecological zone of Tanzania

Variety	Yield potential (t/ha)	Variety characteristics	Maturity	Target zone/AEZ
Staha	6.5	Open pollinated, white flint/dent streak tolerant	NA	Low altitude
Kilima	7.5	Open pollinated, white flint/dent good standability	Late maturity 120 to 150 days	Medium and high altitude
TMV 1	6.3	Open pollinated, white flint, medium maturity, streak resistant	Intermediate maturity 65 days	Low and medium altitude
TMV 2	9.0	Open pollinated, white flint, large ears	NA	Medium and high altitude
Kilima ST	7.5	Open pollinated white flint/dent, good standability, and streak tolerant	NA	Medium and high altitude
Katumani ST	4.3	Open pollinated white dent early maturity, streak tolerant	108 days	Low altitude
PAN 6549, 695, 6481	7.5	Hybrid, white, hard flint and good standability	NA	Medium altitude

Source: Modified from Lyimo et al. (2014); SUBAGRO (2015) (http://www.subaagro.com/index_files/OPV.htm); NA – not available

Table 14: Characteristics of common rice grown in Eastern Zone of Tanzania

Rice Variety	Yield potential (t/ha)	Variety characteristics	Maturity (days)	Target zone/AEZ
TXD 85	5.7 to 6.0	Non aromatic, moderately susceptible to RYMV	110 to 120	Rain fed lowland and irrigated
TXD 88	6.0 to 7.0	Non aromatic, moderately susceptible to RYMV	110 to 116	Rain fed lowland and irrigated
TXD 306	4.5 to 5.5	Semi aromatic, highly susceptible to RYMV	120 to 125	Rain fed lowland and irrigated
NERICA 1	3.0 to 4.5	Aromatic upland rice	93	Upland rain fed
NERICA 7	4.0 to 5.5	Non aromatic	90	Upland rain fed
WAB 450- 12-2-BL1-DV4	5.0 to 6.0	Non aromatic	98	Upland rain fed
SUPA	2.0 to 3.0	Aromatic, highly susceptible to RYMV	120 to 135	Rain fed lowland

Source: ARI KATRIN (2012)

Given the right climatic and altitude conditions for variety choices, the attempt to increase crop yield rest on the choice of right inputs (seeds and fertilizers based on nutrient requirements) and appropriate agronomic practices. Evidence showed that for less fertile soils with low N, P, and K and under rain-fed conditions the high actual yield of 4.4 t/ha for maize was obtained when a combination of 80 kg N/ha, 40 kg P/ha and 30 kg K/ha were applied (Table 15) (URT, 2014). For rice, using SARO TXD 306 variety high yield of 5.0 t/ha (91% of potential yield) was obtained when a combination of 120 kg N/ha (2 bags of urea/acre), 40 kg P/ha (3/4 bag of DAP) and 20 kg K/ha (1/3 bag Murate of Potash (MoP)/acre) was applied (Table 16).

Table 15: Staha maize yield obtained under different fertilizer combination to replenish low plant nutrient in soil in Eastern Zone of Tanzania

N rate (kg N/ha) [Approx. Bag Urea/acre]	P rate (kg P/ha) [Approx. Bag DAP/acre]	K rate (kg K/ha) [Approx. Bag MoP/acre]	Staha Maize yield (t/ha)
0	0	0	1.0
30 [0.5]	0	0	1.5
60 [1.0]	0	0	2.2
80 [1.5]	0	0	3.3
30 [0.5]	20 [1/3]	20 [1/3]	3.3
60 [1.0]	20 [1/3]	20 [1/3]	3.5
80 [1.5]	20 [1/3]	20 [1/3]	3.8
30 [0.5]	40 [3/4]	20 [1/3]	2.8
60 [1.0]	40 [3/4]	20 [1/3]	4.0
80 [1.5]	40 [3/4]	20 [1/3]	4.4

Source: Modified from URT 2014; DAP – Di ammonium phosphate; MoP – Murate of Potash

Table 16: Rice (SARO TXD 306) yield obtained under different fertilizer combination to replenish low plant nutrient in soil in Eastern Zone of Tanzania

N rate	P rate	K rate	Soil-water conservation	Rice SARO TXD 306 yield (t/ha)
0	0	0	Majaruba and flood irrigation	2.40
30	0	0	Majaruba and flood irrigation	2.70
60	0	0	Majaruba and flood irrigation	3.20
80	0	0	Majaruba and flood irrigation	3.30
120	0	0	Majaruba and flood irrigation	4.20
30	20	20	Majaruba and flood irrigation	3.00
60	20	20	Majaruba and flood irrigation	3.80
80	20	20	Majaruba and flood irrigation	4.40
120	20	20	Majaruba and flood irrigation	4.20
30	40	20	Majaruba and flood irrigation	3.50
60	40	20	Majaruba and flood irrigation	4.00
80	40	20	Majaruba and flood irrigation	4.50
120	40	20	Majaruba and flood irrigation	5.00

Source: Modified from URT (2014)

The medium yields of 3.3 t/ha for maize and 3.5 t/ha for rice can be obtained with use of ½ bag of Urea/acre in combination with 1/3rd bag of DAP and MoP or NPK formulation that can provide equivalent amount nutrients. Based on soil fertility results fertilizers supplying potassium is needed in most of the project sites because K is low to medium (Section 4.1.2). However, the decision on the amount of fertilizer to use is further guided by the economic analysis based on the cost and price of crops harvested (Section 4.5).

4.3. Socio-economic situation

4.3.1. Poverty profiles

As noted earlier, promotion of CSA options in South Nguru Mountains Landscape will inevitably involve introduction of new farming technologies or significant transformation of existing farming practices. One of the important determinants of adoption of soil and water conservation measures is the level of household capability exemplified by levels of physical, social and financial assets (Jones, 2002; World Bank, 2000). In addition, given the increasing realization that communities are highly differentiated (Ellis and Allison, 2004) it was necessary to ensure that ideas and realities from all wealth groups are equally represented. These facts necessitated exploration of household assets dynamics through wealth ranking that harness people's own view on poverty while at the same time encompassing the widely accepted multidimensional nature of poverty (Narayan et al., 2000; Ravnborg, 2003).

Common characteristics used to define wealth categories across study villages are summarized in Table 17, whereas a detailed account of the wealth criteria and indicators for each of the survey villages is given in Annex 6. It is important to note that the term "non-poor" in the context of this study is rather relative and does not necessarily correspond to wealth or income much above the conventional poverty line.

Table 17: Indicators and criteria for wealth at Bwage, Digoma, Kinda and Mndela village within South Nguru Mountains Landscape in Mvomero district, Tanzania

Community defined indicators	**Community defined wealth categories and criteria**			
	Non-poor	**Less-poor**	**Poor**	**Poorest**
House and housing condition	Iron sheet roof, burnt bricks and cement made wall Smooth floor made by cement and or tiles Window made of finished lumber with wire mesh and door with top made of finished lumber Houses installed with solar panels for household electricity	Iron sheet roof, burnt mud-bricks and cement made wall -Smooth floor made by cement or dusty -Window made of finished lumber and door made of finished lumber	Iron sheet roof or thatched with grasses, burnt bricks or mud wall Dusty floor Window covered with brick and door made of rough lumber or iron sheet	Roof thatched with grasses or palm leaves, wall made of poles and mud Dusty floor Windows covered with palm leaves or no and door made of iron sheet or palm leaves
Number and type of livestock owned	Cattle 1 to 20, goats 5 to 20, pigs 1 to 4, chicken 10 – 30 and ducks 10 and above.	Cattle 0 to 5, goats 1 to 10, pigs 0 – 3, chicken 5 to 20 and ducks 0 - 10	Own no cattle, goats 0 – 5, chicken 2 – 15 and ducks 0 to 5	Own no cattle, goat 0 to 4, chicken 0- 5 and duck 0 to 4
Size of farm/land owned	3 - 30 acres	1 - 10 acres	Can own 0.5 - 5 acres	Can own 0.5 - 2 acres
Farm implement and machinery	Hire tractor, casual labor or combination of two	Hire tractor, casual labor, combination of two	Hand hoe and themselves	Hand hoe and themselves
Type and number of transport facilities owned	0 -1 car,1 Motorcycle or above and 0 -1 or above bicycle	0 - 1 Motorcycle and 0 -1 bicycle	0 - 1 bicycle	Never own any transport facility
Farm yield (Harvest)	Harvest is normally	Harvest is normally	Harvest is usually low	Very low or no harvest

Community defined indicators	Community defined wealth categories and criteria			
	Non-poor	Less-poor	Poor	Poorest
	high produce	average		
Food security (number of meals a day)	Have adequate and can afford three meals a day, and can choose what to eat	Three meals a day and may choose what to eat, eat sometime cannot choose	Two meal a day and have no choice of what to eat	One meal or two a day but with difficult and completely have no choice of what to eat
Ability to access health services	Can afford health care (Treatments) from private hospitals found around the area and outside Morogoro region	Can afford health care (Treatments) from private hospital found around the area but may not go outside Morogoro region	Acquire health services from public health centres available in the village and within the district	Acquire health services from public health centres available in the village but with difficulties in affording the costs involved
Ability to send children to school	Can support/send children for primary education and secondary education in private school available in and outside Morogoro region	Can support/send children for primary education and secondary education in private or public school available in and outside Morogoro region	Send children to public primary schools Also can support children to secondary education in public schools but with difficulties.	Send children to public schools and only primary level but with difficulties _And sometime do not send children to school
Income generating activity undertaken (Off-farm activities)	Retail shops, store rooms and houses for rent, trading in agricultural produces, milling machines ,transportation and generators generating electricity for sale	Retail shop, occasionally engaged in trading agricultural produces; some may operate milling machines and house for rent	Casual labour, make and sell local brew, sell agricultural produce very occasionally, may work as mason and *bodaboda*.	Casual labour

On the basis of the community defined wealth criteria, non-poor households are characterised by having houses made of brick walls, cement floor and iron roofs; land holdings of 3 - 30 acres, up to 20 cattle, 5 - 20 or more goats, 1 to 4 or more pigs, 10 - 30 chicken, sending their children to high quality private schools up to secondary education, hiring labour, owning bicycles; sometimes owning varying numbers of motorbikes, vehicles and non-farm businesses, and normally being food sufficient all the year. The less-poor and poor are characterised by increasingly fewer of all these assets, increased reliance on selling labour, and worsening ephemeral food insecurity. The poorest have little or no land, no livestock; rely entirely on selling labour or food aid; and are food insecure almost the whole year.

Across all villages studied, one pertinent feature of the non-poor and less-poor was the tendency to engage in more non-farm activities such as trading, milling machines and transportation service provision.

Regarding access to and use of livelihood assets, two things have been clearly articulated from the general literature on poverty (Ellis and Mdoe, 2003; Ellis and Allison, 2004). First, ownership or access to assets and their efficient productive uses are the fundamental bases by which the poor can construct their own routes out of poverty (World Bank, 2000). Second, poverty reduction process proceeds in a sequence of asset accumulation that involves trading-up assets in sequence such as chickens to goats to cattle to land; or, cash from non-farm income to farm inputs to higher farm income to land or to livestock (Ellis and Mdoe, 2003). Apparently, a closer look at the community defined wealth indicators and criteria in Table 18 reveals that one of the valuable assets for the poor and poorest is chicken. The implication is that, interventions that focus on addressing constraints that hinder the poor and poorest from undertaking efficient chicken production can help them climb out of poverty. As they proceed on their way out of poverty, in the process of accumulating and trading-up assets, their capability to adopt CSA options is likely to be enhanced as well.

Proportion of household in each wealth category are given in Table 18, which provides bench mark for later evaluation of how the program attain economic resilience as one of the key elements of adaptation to the impacts of climate change.

Table 18: Percent of households in each wealth categories at Bwage, Digoma, Kinda and Mndela village within South Nguru Mountains Landscape in Mvomero district, Tanzania

Village	Total households	Wealth categories				Total
		Non-poor	Less-poor	Poor	Poorest	
Bwage	364	2.2	19.2	49.7	28.8	100
Digoma	454	3.1	24.7	47.8	24.4	100
Kinda	326	2.5	10.4	62.0	25.2	100
Mndela	263	1.1	5.7	37.3	55.9	100
All villages	**1,407**	**2.3**	**16.4**	**49.6**	**31.6**	**100**

According to URT (2008), in order to attribute dynamics observed in wealth categories of particular households such assessment need to be combined with a well-designed in-depth interviews to those households that will show either movement to a higher or lower wealth categories, as well as appropriate key informants in respective communities. This is because factors other than those controlled by a particular program/project such as employment opportunities and emergence of cash crop cultivation opportunities are equally important in determining the dynamics of wealth categories.

Another notable feature from Table 18 is that the majority of household in the surveyed villages from the South Nguru Mountains Landscape are poor (49.6%) poorest (31.6%) all together accounting for 81.2% of total households. **Thus, the non-poor and less-poor households that can be considered to have enough capability to adopt CSA options represent 18.8% only.**

4.3.2. Population characteristics

The variables selected to describe the main socio-economic characteristics of the sample were educational level and dependence ratio (Table 19). Literacy level was encouraging in all villages surveyed because there were more 70% who had primary education.

Makauki (1999) noted that ability to read and write enhances adoption of new technologies whose dissemination involve simple leaflets, pamphlets, posters newspapers or other simple written materials. In this case, primary education is considered adequate to enhance adoption of new technology.

Table 19**:** Socio-economic profile of sample households at Bwage, Digoma, Kinda and Mndela village within South Nguru Mountains Landscape in Mvomero district, Tanzania

Characteristics	Value			
	Bwage	Digoma	Kinda	Mndela
Percent of respondents attended primary school education (%)	73.5	87.2	79.4	87.9
Percent of respondents attended secondary education (%)	8.8	0.0	2.9	3.0
Percent of respondents attended college education (%)	5.9	2.6	0.0	0.0
Percent of respondents with no formal education (%)	11.8	10.3	17.6	9.1
Average dependency ratio†	2.269 (0.398)	1.800 (0.269)	1.466 (1.08)	1.634 (0.350)
Native to the area (%)	44.1	89.7	94.1	93.9
Migrated to the area (%)	55.9	10.3	5.9	6.1

†Numbers in brackets are standard error of the mean

Dependency ratio i.e. the ratio of number of people below 18 and those above 60 years to the remaining members of the household can be used as a measure of labour supply at household level. The higher the dependency ratio the low the labour supply and vice versa. The dependency ratio greater than 1.4 found in this study is an indication that a household in the surveyed villages has slightly more people to take care of. This raises concerns regarding the abilities of these families to effectively engage in interventions that require high labour inputs such as construction of terraces especially when there is no significant corresponding increase in crop yields (Tenge and Hella, 2005). In this case, **promotion of sustainable land management practices in the villages located in the highlands may need to learn from pineapple contour farming in Uluguru Mountains Landscape, which is relatively less labour intensive as an alternative technology for soil and water conservation (URT, 2009).**

This study also looked at the nature of migration in the four surveyed village. With exception of Bwage village with 55.9% of respondents migrated in the area, more than 89% of respondents in the rest of the villages report to have been born and living in the same village. According to some studies, this has implications in receptivity to change. It is generally maintained that homogeneous communities tend to be more conservative compared to heterogeneous ones (Weeks, 1981). Migration brings people together who have different views of the world, ways of approaching life, attitudes, and behaviour patterns that stimulates the urge to accept new ideas (*Ibid*).

Goldthorpe (1978) cited in URT (2009) noted that migrants are likely to be more enterprising people. Secondly, there may be positive demographic factors associated with migrants as migrant communities are characteristically short of older people and teenagers, which mean that the ratio of economically active people in the community is higher than would be the case with settled groups. Finally, migrants may be free from the customary constraints on enterprise and initiative that are effective in the home society.

4.3.3. Crop production information and cost of hiring land

Table 20 and Table 21 show average farm areas put under different crops and proportion households growing different crops among the sampled households in the South Nguru Mountains landscape, respectively. Maize was the most common crop grown by the majority (97.1% to 100%, 1.68 acres per household) across the entire landscape.

Table 20:Mean land size in acres used to grow different crops in the surveyed villages from South Nguru Mountain Landscape in Mvomero district, Tanzania

Crops	Villages									
	Digoma (n = 39)		Bwage (n = 34)		Mndela (n = 33)		Kinda (n = 34)		All villages (n = 140)	
	Mean	Std. Error of Mean	Mean	Std. Error of Mean	Mean	Std. Error of Mean	Mean	Std. Error of Mean	Mean	Std. Error of Mean
Maize	1.18	0.12	3.31	0.52	1.45	0.13	0.82	0.20	1.68	0.16
Rice	0.67	0.13	0.81	0.23	0.00	0.00	0.00	0.00	0.38	0.07
Beans	0.04	0.03	0.00	0.00	0.74	0.10	0.38	0.11	0.28	0.05
Sesame	0.09	0.05	0.85	0.23	0.00	0.00	0.00	0.00	0.23	0.06
Peas	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bananas	0.26	0.09	0.00	0.00	0.03	0.03	0.07	0.06	0.10	0.03
Cocoa	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Cardamon	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Tomatoes	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.01
Cassava	0.24	0.07	0.00	0.00	0.03	0.03	0.00	0.00	0.07	0.02
Mangoes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oragnes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avocado	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Teak trees	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grevillea trees	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Rice and beans came next in dominance after maize but they occurred in different biophysical niches of the landscape. Rice was cramped to the humid lowland village (61.5% of respondents, 0.87 acres per household) and dry lowland village (47.1% of respondents, 0.81 acres per household).

Table 21: Percent of respondents who grow different crops in the surveyed villages from South Nguru Mountain Landscape in Mvomero district, Tanzania

Village	Wealth category	Crops															
		Maize	Rice	Beans	Sesame	Peas	Sunflower	Banana	Cocoa	Cardamon	Tomatoes	Cassava	Mangoes	Oranges	Avocado	Teak trees	*Grevillea robusta*
Digoma village	Non-poor (n = 6)	100	83.3	0	0	0	0	50	16.7	0	16.7	16.7	0	0	0	0	0
	Less-poor (n = 6)	100	50	0	0	16.7	0	83.3	0	0	0	66.7	0	0	0	0	0
	Poor (n = 20)	100	65	10	5	0	0	5	0	0	10	25	0	0	0	0	0
	Poorest (n = 7)	100	42.9	0	28.6	0	0	14.3	0	5	0	28.6	0	0	0	0	0
	Overall (n = 39)	100	61.5	5.1	7.7	2.6	0	25.6	2.6	2.6	7.7	30.8	0	0	0	0	0
	Chi-square significance	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
Bwage village	Non-poor (n = 4)	100	50	0	25	0	0	0	0	0	0	0	0	0	0	0	0
	Less-poor (n = 8)	87.5	37.5	0	87.5	0	0	0	0	0	0	0	0	0	0	0	0
	Poor (n = 13)	100	69.2	0	46.2	0	0	0	0	0	7.7	0	0	0	0	0	0
	Poorest (n = 9)	100	22.2	0	33.3	0	0	0	0	0	0	0	0	0	0	0	0
	Overall (n = 34)	97.1	47.1	0	50	0	0	0	0	0	2.9	0	0	0	0	0	0
	Chi-square significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mndela village	Non-poor (n =1)	100	0	100	0	0	0	0	0	0	0	0	0	0	100	0	0
	Less-poor (n = 2)	100	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
	Poor (n = 19)	100	0	78.9	0	0	0	15.9	0	0	5.3	10.5	5.3	10.5	5.3	0	0
	Poorest (n = 11)	100	0	81.8	0	0	0	9.1	0	0	0	0	9.1	18.2	0	0	0
	Overall (n = 33)	100	0	81.8	0	0	0	12.1	0	0	3	9.1	6.1	12.1	6.1	0	0
	Chi-square significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS
Kinda village	Non-poor (n = 2)	100	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0
	Less-poor (n = 1)	100	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
	Poor (n = 19)	94.7	0	84.2	0	0	0	10.5	0	0	0	0	0	0	0	0	0
	Poorest (n = 12)	100	0	66.7	0	0	0	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
	Overall (n = 34)	97.1	0	73.5	0	0	0	8.8	2.9	2.9	5.3	2.9	2.9	2.9	2.9	2.9	2.9
	Chi-square significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS

NS = Not significant; * = significant at 0.05 level of significance; ** = significant at 0.01 level of significance

On the other hand, beans were confined to both humid windward (81.8% of respondents, 0.74 acres per household) and sub-humid leeward (73.5% of respondents, 0.38 acres per household) highlands. Sesame was another dominant crop grown in the dry lowland (50% of respondents, 0.85 acres per household) to a great extent and meagrely in humid lowland village (7.7 % of respondents, 0.09 acres per household). Cassava was meagrely famous in the landscape mostly grown in humid lowland village (30.8% of respondents, 0.24 acres per household) and sub-humid leeward highland (2.9% of respondents, < 0.001 acre per household) and humid windward highland (9.1% of respondents, 0.03 acres per household) but not encountered in the dry lowland. Banana was the least famous of all crops that occurred in the same areas as cassava.

Overall, the notable feature is the fact that except for rice and sesame, the current practice regarding crops grown in different villages surveyed did not match the prevailing biophysical characteristics as identified during land suitability evaluation. This suggests that communities in the surveyed villages have failed to grow crops that optimize their land productivity. This practice can have negative repercussions on the environment and sustainability the cropping systems (FAO, 1993; Moody et al., 2008). Discrepancy between actual practice and land suitability evaluation results could be acceptable if farmers have developed farm management practices to counteracts or alleviate the limiting factors identified from land evaluation exercises (Cools et al., 2003; Ziadat and Sultan, 2011). However, results from this study do not support this possibility because, with meagre exceptions, farmers across the surveyed villages hardly practice any sustainable land management practices.

Therefore, in order to optimal agricultural production in the South Nguru Mountains Landscape there will be a need for transformation involving switching between crops in different microenvironments, and/or adoption of appropriate technologies capable of overcoming the identified limiting factors. Successful implementation of such recommendation will require a well sought mechanism that will enhance transformation of the farming system. As Ngambeki and UNECA (2003) put it, on-farm trials will be necessary to enable farmers to evaluate adaptation and verification of the appropriate farm management technologies to their social and biophysical realities.

4.3.4. Perceptions of local people on soil erosion, and trends in crop yields and soil fertility

4.3.4.1. Perceptions on soil erosion as a problem

Statistical analysis showed no significant association between wealth categories and perception of soil erosion as a problem. However, there was significant association (χ^2 = 12.38; df = 3; p = 0.006) between village and perception of soil erosion as a problem (Figure 18).

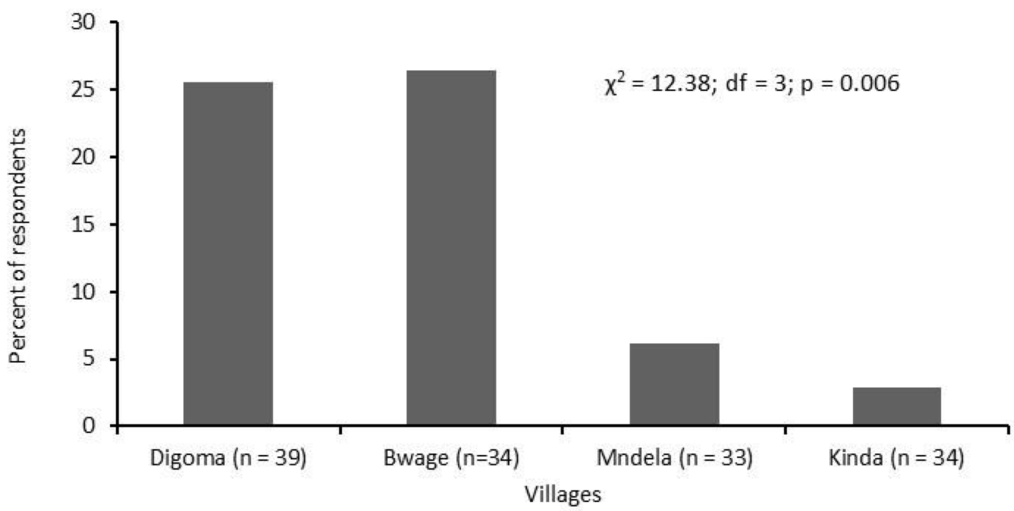


Figure 18: Percent respondents who perceived soil erosion as a problem in the surveyed villages from South Nguru Mountain Landscape in Mvomero district, Tanzania

4.3.4.2. Perceptions on trends in crop yields and soil fertility

Respondents' perceptions on trends in crop yields and soil fertility are presented in Table 22 and Figure 19, respectively.

Table 22: Percent of respondents on perceived trends in crop yields in the surveyed villages from South Nguru Mountain Landscape in Mvomero district, Tanzania

Village	Wealth category	Trends in crop yield			
		Increased	No change	Decreased	Total
Digoma	Non-poor (n = 6)	66.7	0	33.3	100
	Less-poor (n = 6)	33.3	0	66.7	100
	Poor (n = 20)	15	15	70	100
	Poorest (n = 7)	0	28.6	71.4	100
	Overall (n = 39)	23.1	12.8	64.1	100
	Chi-square significance	NS			
Bwage	Non-poor (n = 4)	25	0	75	100
	Less-poor (n = 8)	37.5	12.5	50	100
	Poor (n = 13)	23.1	15.4	61.5	100
	Poorest (n = 9)	11.1	55.6	33.3	100
	Overall (n = 34)	23.5	23.5	53	100
	Chi-square significance	NS			
Mndela	Non-poor (n =1)	0	0	100	100
	Less-poor (n = 2)	0	50	50	100
	Poor (n = 19)	0	36.8	63.2	100
	Poorest (n = 11)	0	63.6	36.4	100
	Overall (n = 33)	0	45.5	54.5	100
	Chi-square significance	NS			
Kinda	Non-poor (n = 2)	50	0	50	100
	Less-poor (n = 1)	0	100	0	100
	Poor (n = 19)	0	42.1	57.9	100
	Poorest (n = 12)	0	58.3	41.7	100
	Overall (n = 34)	2.9	47.1	50	100
	Chi-square significance	**			
All villages	Non poor (n = 13)	46.2	0.0	53.8	100.0
	Less-poor (n = 17)	29.4	17.6	53.0	100.0
	Poor (n = 71)	8.4	28.2	63.4	100.0
	Poorest (n = 39)	2.6	53.8	43.6	100.0
	Overall (n = 140)	12.9	31.4	55.7	100.0
	Chi-square significance	***			

NS = Not significant; * = significant at 0.05 level of significance; ** = significant at 0.01 level of significance; *** = Significant at 0.001 level of significance

Overall, respondents who perceived an increase in crop yields (12.9% of all respondents) were fewer compared to those who perceived decreased crop yields (55.7 % of all respondents) or no change in crop yields (31.4 % of all respondents) over time.

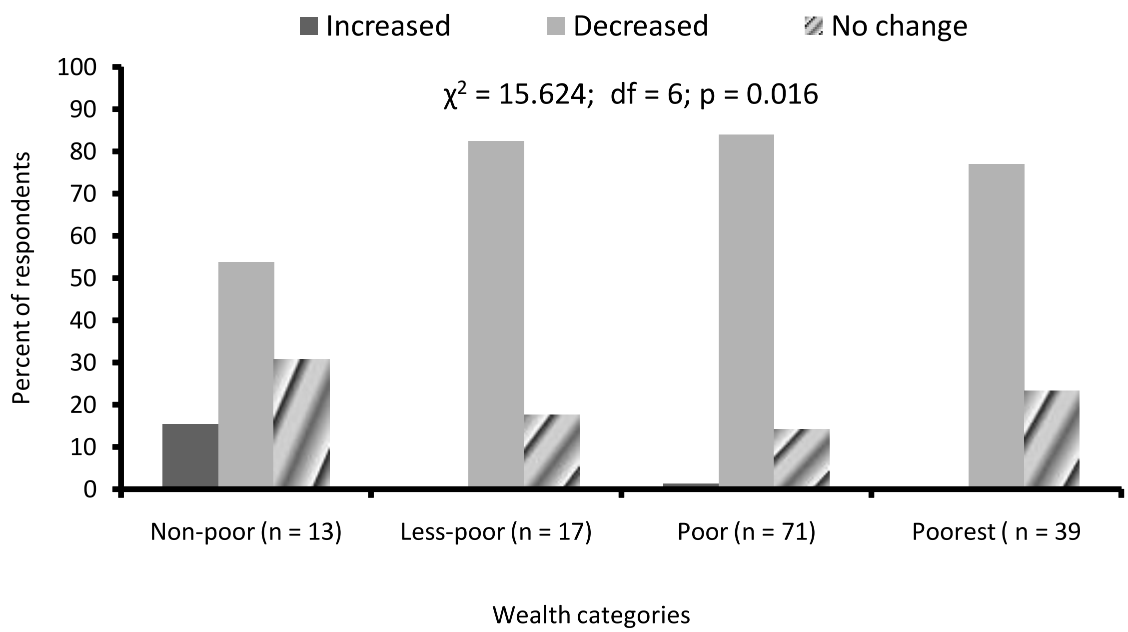


Figure 19: Percent of respondents on perceived trends in crop yields in the surveyed villages from South Nguru Mountain Landscape in Mvomero district, Tanzania

Generally, though not always statistically significant across villages, the non-poor (6 out of 13 respondents or 46.2%) and less-poor (5 out of 17 respondents or 29.4%) were more likely to perceive an increase in crop yields than their counterpart poor (6 out of 71 respondents or 8.4%) and poorest (1 out of 39 respondents or 2.6%), which they attributed to regular use of inorganic fertilizers.

Pattern of respondents' perceptions on trend of soil fertility over time was similar to that of crop yields. Overall, more than 50 percent of respondents across wealth categories perceived a decrease in soil fertility over time. The proportion of households who perceived a decrease in soil fertility over time was similar and significantly high (χ^2 = 15.624; df = 6; p = 0.016) for less-poor, poor and poorest households than the non-poor households. Conversely, though to a small extent (3 out of 13 respondents or 15%), the non-poor households were the only ones that perceived an increase in soil fertility over time; which they too, attributed to regular use of inorganic fertilizers. Apparently, this could mean that although the non-poor had reported an increase in soil fertility they too implied a decrease over time; the only difference was their ability to circumvent the effects of decline in soil fertility through application of mineral fertilizers to remedy the problem.

The 78 respondents (or 56.7% of all respondents) who perceived a decrease in crop yields and 111 respondents (or 79% of all respondents) who perceived a decrease in soil fertility over time were asked to specify their perceived reasons. There were multiple responses on the perceptions of the respondents on causes of both decreased crop yields and soil fertility that were not statistically associated with wealth categories as shown in Table 23 and Table 24, respectively.

Table 23: Percent of respondents on perceived causes of decreased crop trend in the surveyed villages from South Nguru Mountain Landscape in Mvomero district, Tanzania

Perceived causes of decreased crop yields	Non-poor (n = 7)	Less-poor (n = 9)	Poor (n = 45)	Poorest (n= 17)	All wealth categories (n = 78)	Chi-square significance
Soil deterioration	11.4	11.4	57.1	20.0	100.0	NS
Cannot afford required inputs	8.3	8.3	58.3	25.0	100.0	NS
Drought	13.3	16.7	50.0	20.0	100.0	NS
Inadequate household labour due to aging	0.0	25.0	50.0	25.0	100.0	NS
Pests and diseases	25.0	12.5	50.0	12.5	100.0	NS
Don't know	33.3	33.3	33.3	0.0	100.0	NS

NS = As defined in Table 22

Table 24: Percent of respondents on perceived causes of decreased soil fertility trend in the surveyed villages from South Nguru Mountain Landscape in Mvomero district, Tanzania

Wealth categories	Non-poor (n = 7)	Less-poor (n = 14)	Poor (n = 60)	Poorest (n = 30)	All wealth categories (n = 111)	Chi-square significance
Continuous cultivation without use of any inputs	85.7	85.7	76.7	80	79.3	NS
Soil erosion	0	7.1	5	0	3.6	NS
Use of fire for land predation	0	0	0	3.3	0.9	NS
Livestock damage	0	0	5	0	2.7	NS

NS = As defined in Table 22

In total there were 118 different responses on perceived causes of decline in crop yields across all the surveyed villages. This suggests that most of the respondents perceived more one cause of decline in crop yield. Environmental factors, namely soil deterioration (40% of response) and drought (31% of the response) were the most ubiquitous perceived causes of decreased crop yields (Figure 20). On the other hand, of the socio-economic factors, the most important factor was inability to afford the required external inputs constituting 14% of all responses.

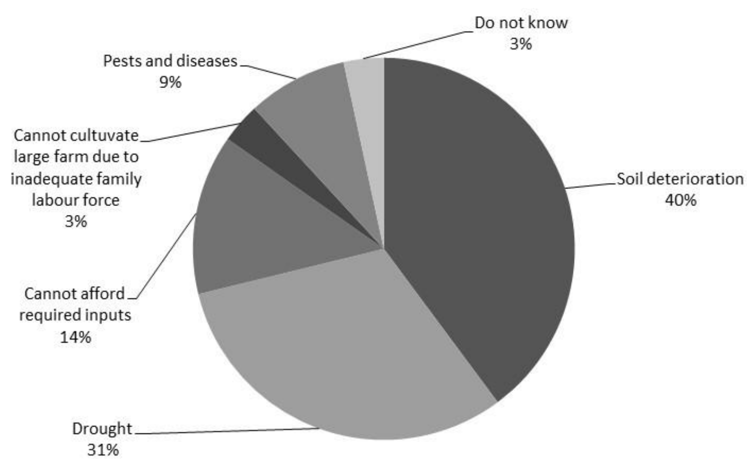


Figure 20: Percent responses on different perceived reasons for decline in crop yields in the surveyed villages from South Nguru Mountain Landscape in Mvomero district, Tanzania

Regarding causes of decreased soil fertility, there were 109 different responses compared to 111 people who responded to the question indicating that some people did not know the reasons for decreased soil fertility. Of the factors attributed to decline in soil fertility, continuous cropping without use of any eternal inputs came out an outstanding perceived cause of decline is soil fertility, which accounted for 86% of all responses (Figure 21).

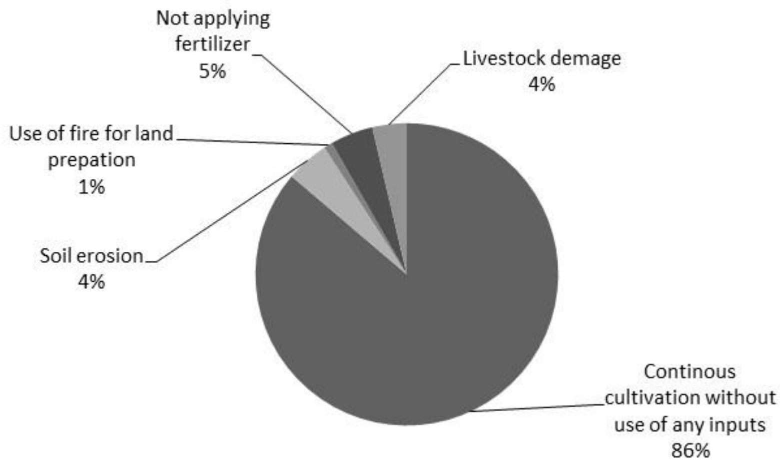


Figure 21: Percent responses on different perceived causes of decline in soil fertility in the surveyed villages from South Nguru Mountain Landscape in Mvomero district, Tanzania

The pattern of perceptions on soil erosion problem is at odd with scientific understanding. Scientifically, it is suggested that Mndela and Kinda villages that are in highland areas are more likely to suffer from soil erosion than lowland villages of Digoma and Bwage. Nevertheless, these results corroborate with Jones (2000, 2002) who found that local communities in highlands of Uluguru Mountains considered landslide to be a problem but not sheet erosion. They, instead recognized land deterioration (or “land being tired”) in farms located in sloping lands, which could signify the ultimate effects of soil erosion, among other things. The unusual oversensitivity on soil erosion problem reported from lowland villages could be attributed to their regular access to environmental conservation information and education (FBD, 2002, 2008; Kuboja et al., 2013). The two villages from the lowland were close to town centres along Dumila-Tanga main road, which made them easily accessible by extension workers throughout the year than the villages in the highlands with poor roads.

4.3.5. Usage and knowledge about soil and water conservation measures

The study investigated levels of usage of six broad measures for soil and water conservation, namely, terraces; tree planting around homestead, as hedgerows or intercropping with crops; natural fallow, improved fallow, crop rotation and organic farming. Results showed multiple responses that had no clear pattern when each practice was examined independently. Thus, the data for all practices were pooled and further analysed to examine pattern in usage of at least one of those practice. Overall, results showed that 36 out of 140 respondents (or 25.7% of all respondents) of all respondents were using at least one of the soil and water conservation measures. Results further showed that significant association (χ^2 = 10.894; df = 3; p = 0.012) between wealth categories and usage of at least one soil and water conservation measures. The non-poor (61.5%) were more likely to practice at least one of the soil and conservation measures than the less-poor (29.4%), poor (18.3%) and poorest (25.6%) (Figure 22).

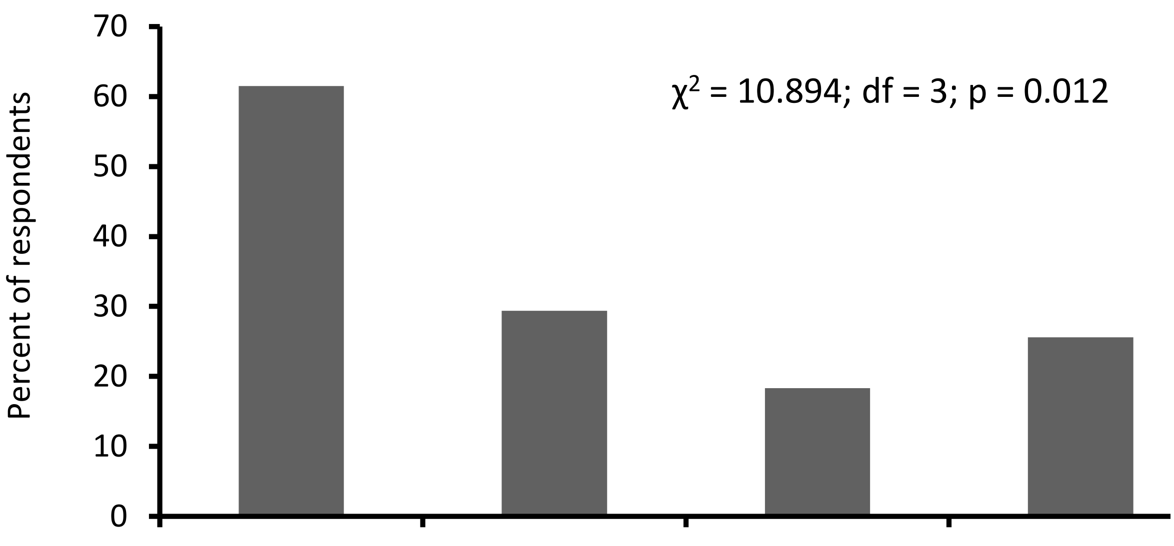


Figure 22: Percent respondents who use any soil and water conservation measure in the surveyed villages from South Nguru Mountain Landscape in Mvomero district, Tanzania

However, differences between villages (data not show) were insignificant ($\chi^2 = 4.128$; df = 3; p = 0.248) although the tendency was less usage of soil and water conservation measures in remote villages i.e. Mndela (22.2%) and Kinda (16.7%) compared to their counterparts in easily accessible areas i.e. Digoma (25.0%) and Bwage (36.1) villages.

Multiple response analysis showed that in total there were 64 different responses on soil and water conservation measures used across all the surveyed villages compared to 36 people who reported to use the practices. This means that most of the people who report to use soil and water conservation were using more than one option. The distribution of different responses is shown in Figure 23.

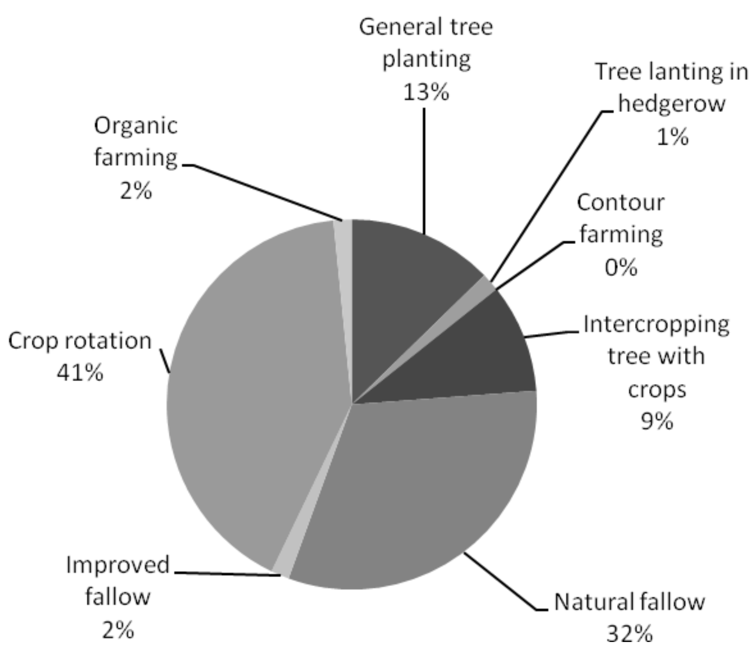


Figure 23: Percent responses on different soil and water conservation measures practiced in the surveyed villages from South Nguru Mountain Landscape in Mvomero district, Tanzania

The most common soil and water conservation measures were crop rotation and natural fallow, which accounted for 41% and 32% of all responses, respectively. Results further showed that contour farming was not practiced at all. The prevalence of crop rotation and natural fallow practices may be ascribed to the fact that community members had knowledge or awareness about the practices, which are known to be indigenous environmental conservation practice in sub-Saharan Africa (Asadu et al., 2008). These results confirm results by Kuboja et al. (2013) who found widespread usage of indigenous soil and water conservation measures than introduced practices.

4.3.6. Market information and pricing mechanisms for agricultural produces

Results on reported sources of crop price information and price setting mechanisms employed by farmers in the surveyed villages is shown in Figure 24 and 25, respectively.

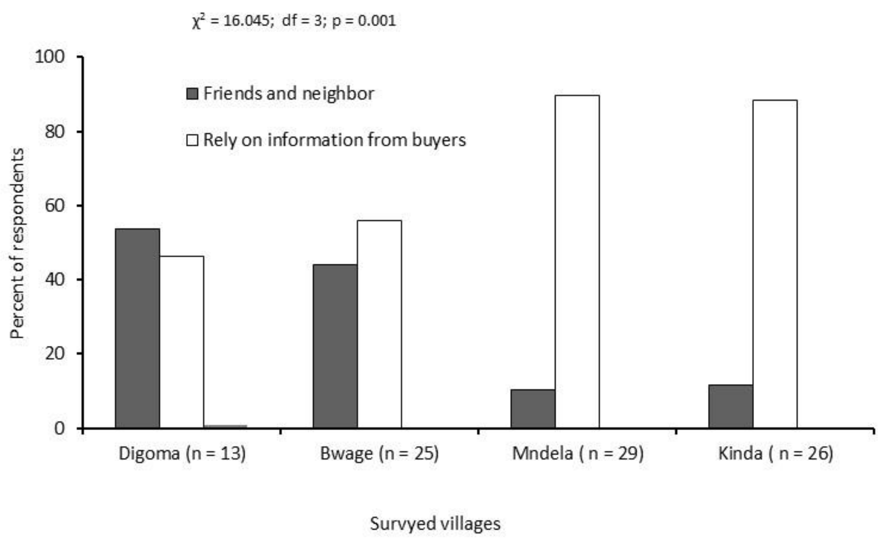


Figure 24: Percent of respondents on sources of price information for agricultural produces among surveyed villages in South Nguru Mountains Landscape in Mvomero district, Tanzania

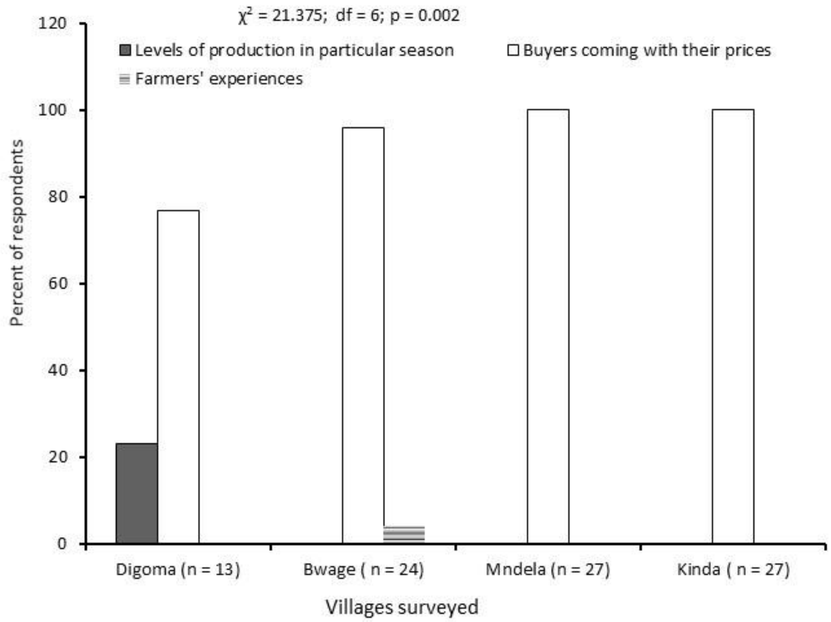


Figure 25: Percent of respondents on bases for setting prices for agricultural produces among surveyed villages in South Nguru Mountains Landscape in Mvomero district, Tanzania

There was significant variation between villages ($\chi^2 = 16.045$; df = 3; p = 0.001) on their sources of crop price information. Digoma and Bwage villages that are close to town centers were more likely to exchanges crop price information among themselves than their counterparts from the most remote villages of Kinda and Mndela who entirely depended on information provided from the buyers. This may suggest that villages close to town centers have more contacts with outsiders than those in remote areas.

On the other hand, results showed that farmers from villages close to town centers were more likely ($\chi^2 = 21.375$; df = 6; p = 0.002) to bargain good farm-gate prices based on their experiences and production level in particular season than their counterparts who solely accept prices set by buyers.

These results clearly show the perfect match between access to market information and farmers' bargaining powers. In this situation, buyers may take advantage of farmers' ignorance of market price to offer very low prices for their produce (Svensson and Yanagizawa, 2009; Courtois and Subervie, 2014). Equally, buyers are reluctant to allow farmers access to reliable market information. For example, Fida Hussein (the only cocoa buyer at Mhonda) was reluctant to share market information during the study. Upon arrival at his compound he furiously refused to be interviewed. These were his words:

> "*Go away with your research! Who are you that you want to access information on prices? This is not supposed to be disclosed! Do you understand?"*

This implies that given the same level of soil productivity, farmers close to town centers are likely earn more income from agriculture produces than those in remote areas. This proposition is supported by studies on market information and pricing of agricultural produce from different African countries. In Mozambique, Kizito reported 12% increase in profit margin for farmers who had crop price information compared to those who had no access. Similar results have been reported in central India (Goyal, 2010), Ghana (Courtois and Subervie, 2014) and Uganda (Svensson and Yanagizawa, 2009).

4.3.7. Marketing and market barriers

There were multiple responses on perceived market barriers across surveyed villages. The most frequently mentioned barriers in order of importance were: poor roads, distance to market, low price offered by buyers, oversized units of measure (lumbesa), low harvest, inadequate buyers, inadequate access to price information, lack of unit among farmers, difficult terrain and inadequate storage facilities.

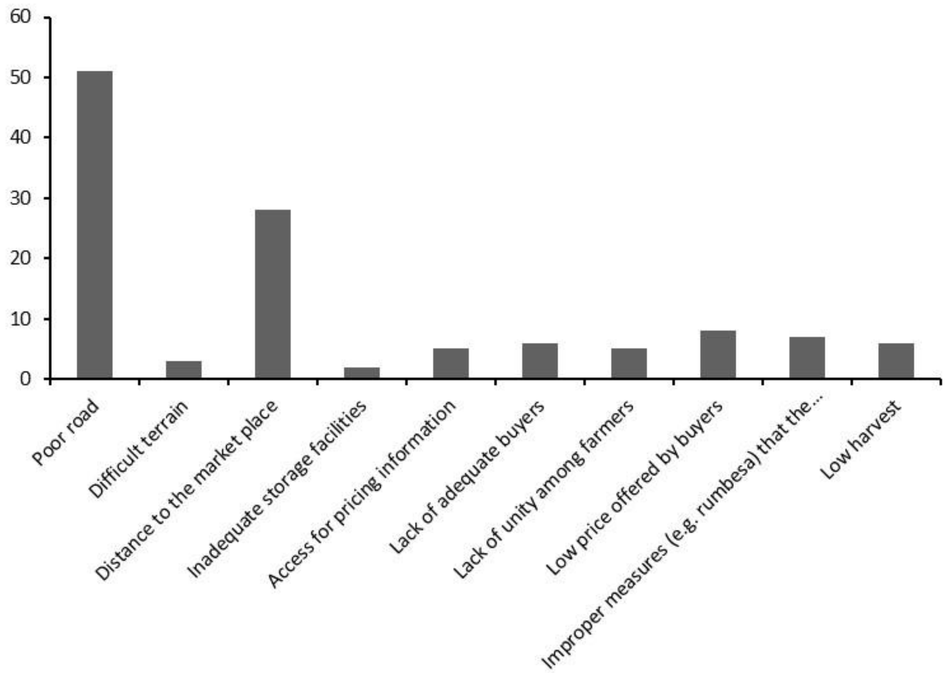


Figure 26: Percent of responses on perceived marketing barriers for agricultural produces among surveyed villages in South Nguru Mountains Landscape in Mvomero district, Tanzania

Most of the identified barriers are directly linked to relative distance of the village from town centres. The most remote villages are unable to participate in the market because higher transportation costs which are linked to poor roads, difficult terrain and inadequate buyers who are able to reach the villages.

4.3.8. Attitude towards environmental conservation

Respondents' attitudes towards environmental conservation were assessed based on their responses on a set of open-ended test questions about self-reported perceptions on pesticide disposal (1 point), fertilizer handling in watershed areas (1point), land preparation methods (1 point), tree cutting (1 point), forest encroachment (1 point), tree planting (1 point), cultural and socio-economic uses of fire (3 points). Based on responses to these questions, the level of attitude towards environmental conservation was determined for each respondent was deduced based on pre-set cut-off points[4].

Results revealed quite impressive levels of attitudes towards environmental conservation across villages (Table 25).

Table 25: Percent of respondents on their attitudes towards environmental conservation in surveyed villages from South Nguru Mountain Landscape in Mvomero district, Tanzania

Levels of attitude	Percent of respondents				
	Bwage (n = 34)	Digoma (n = 39)	Mndela (n = 33)	Kinda (n = 34)	Overall (n = 140)
Negative attitude	0.0	0.0	0.0	0.0	0.0
Weak positive attitude	0.0	0.0	0.0	2.9	.7
Medium positive attitude	0.0	0.0	3.0	14.7	4.3
Highly positive attitude	100.0	100.0	97.0	82.4	95.0
Total	**100**	**100**	**100**	**100**	**100**

The proportion of respondents who scored highly positive attitudes environmental conservation, which ranged from 82.4% in Kinda village to 100% in both Bwage and Digoma villages, were generally high. The implication of these results is that communities in these areas are likely to support conservation initiatives (Grumbine 1994; Jacobson 1995; Bauer 2003; Christensen 2004). The highest positive attitude towards conservation could be a result of continued conservation and development interventions mainly through the Tanzania Forest Conservation Group (TFCG) since 2004 which created community awareness on conservation and provide conservation knowledge to most of the villages including the surveyed villages (Menegon et al., 2008).

[4]Total scores of "0", "1 – 2", "3 – 4" and "5 – 9" signify negative attitude, weak positive attitude, moderate positive attitude and high positive attitude, respectively

4.4. Causal analysis of principle problems in agriculture and natural resources

Climate smart agriculture focuses on sustainable land management (SLM) technologies that are capable of enhancing crop production with minimum depletion of soil and water resources while at the same time increasing the resilience of the farming systems and capacity to sequester carbon and mitigate the impacts of climate change (World Bank, 2006[5]; FAO, 2010[6]). This interrelation between climate smart agriculture and land, forest and water resources necessitated identification and analysis of the problems related to agriculture, water and forest resources based on local people's perspective. The detailed results of the analyses are presented in Annex 7, 8 and 9; the subsequent sub-sections provide a concise presentation of the participatory problem analyses across agriculture, forest and water sectors.

4.4.1. Agriculture

The principle problem for the agriculture sector was decline in crop yields record across the agro-ecological zones although it was more severe in the dry areas. The immediate causes for declining crop yields were drought, decline in soil fertility and pests and diseases (Annex 7). Drought, pests and diseases are due to long-term environmental degradation. On the other hand, decline in soil fertility is a result of a combination of interrelated factors including continuous cropping without any external inputs due to inadequate incomes to buy agricultural inputs in the absence of a clear subsidy program, and reduced fallow period as a result of increased population from natural birth and immigration of people coming to acquire land for farming and low incomes emanating from not only low crop yields but also unfair markets that dictate unfavourable prices to farmers. This is aggravated by inadequate extension services due to low motivation amongst extension workers to support farmers or take time to stay in the village. The root causes of all these is inadequate technical and institutional support from the ward and district levels, which closely relate to inherent inadequate capacities within local governments. Based on this analysis, it is recommended that capacity building initiatives be

[5]World Bank (2006). Sustainable Land Management: Challenges, Opportunities, and Trade-offs. Washington, DC 20433. The International Bank for Reconstruction and development/The World bank.

[6]FAO (2010). "Climate-Smart" Agriculture. Policies, Practices and Financing for Food Security, Adaptation and Mitigation. FAO, Rome, Italy

designed to support communities concurrently with local government staff who will continue to support the communities beyond the project life. Working through community based paraprofessionals who can be trained as trainers to train their fellow community members through on-farm demonstration and on-site support appears to be an appropriate solution as suggested by Bhatia and Buckley (1998) working in the Uluguru Mountains and Kajembe et al. (2005) working in Arumeru Mountains. However, there is a challenge to develop a self-motivation mechanism for paraprofessionals who otherwise cease to function once a project that supported their training ends. **Supporting the paraprofessionals to operate as private entrepreneurs who establish and manage demonstration plots as their own show cases for marketing of their services under a business basis can help to circumvent their inherent disincentive syndrome.**

4.4.2. Forest resources

Across the surveyed villages, the principle problem under forest resource management is deforestation. Deforestation is directly caused by haphazard tree cutting to meet the immediate needs for farm expansion, timber and charcoal making; and wild fires (Annex 8). Clearing forests tor farm expansion is a result of decline in soil fertility in the ordinary farms in order to meet the need to feed the ever-increasing population. This happens because extension services are inadequate and have failed to support alternative faring practices that can maintain soil fertility. On the other hand, tree cutting for charcoal making and timber is a result of not only inadequate institutional systems to support alternative income generating activities but also the need to get additional source of income as income from agriculture continues to decline. The bottom-line is the defective governance and development supervision systems at village, ward and district levels that fail to enforce the respective law and bylaws to safeguard the forest resources as corruption prevails.

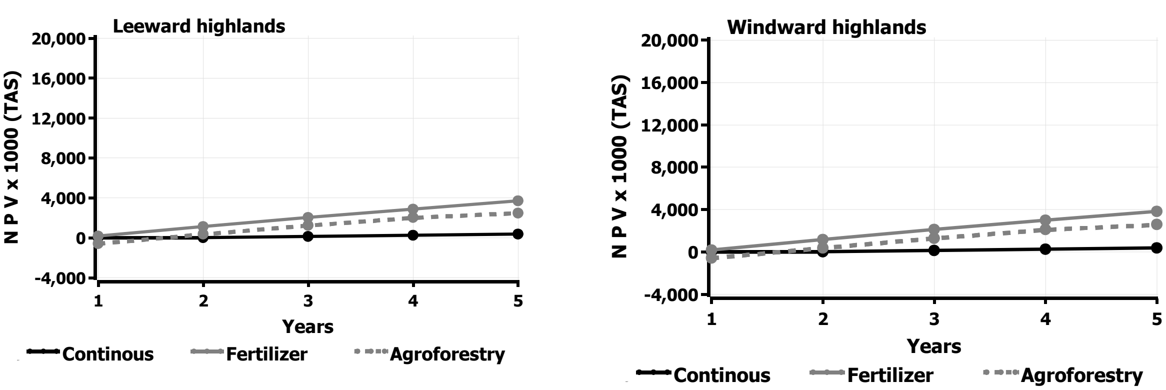
4.4.3. Water resources

The principle water resource problems across all surveyed villages were flooding and decline in water flow (Annex 9). The immediate causes are related to prevalence of unsustainable farming practices that include shifting cultivation, clearing forests for farm expansion, cultivation along the river banks and mining activities especially in the upland areas. Loss of soil fertility in old farms necessitates shifting to another area in search of fertile land. The government introduced the agricultural input subsidy system but the system does not work as it is surrounded by several operational challenges including late delivery or no delivery at all especially in the upland areas, and various forms of bad governance. This can easily happen because most people are unaware of the causes and consequences of environmental changes. This is aggravated by the ever increasing population which increases demand on forest products and more land for food production. As agricultural production declines, household incomes decline too; this leaves communities with no option but to engage in charcoal making, lumbering and mining. Furthermore, increased drought and limited access to appropriate irrigation technologies has meant that people have to cultivate along the river banks in order to avoid crop failure. All these issues arise because there are inadequate agricultural and forestry extension services and few options for off-farm income activities. There is also little or no supervisory support from the local government authorities at all levels, which tends to provide conditions that favour perpetuation of these problems.

4.5. Economic analysis of different crops/crop combination

4.5.1. Maize

Overall, financial analysis for the medium term (5 years) shows that maize production in any of the cropping systems is less profitable in the highlands compared to either humid or dry lowland areas (Figure 27).



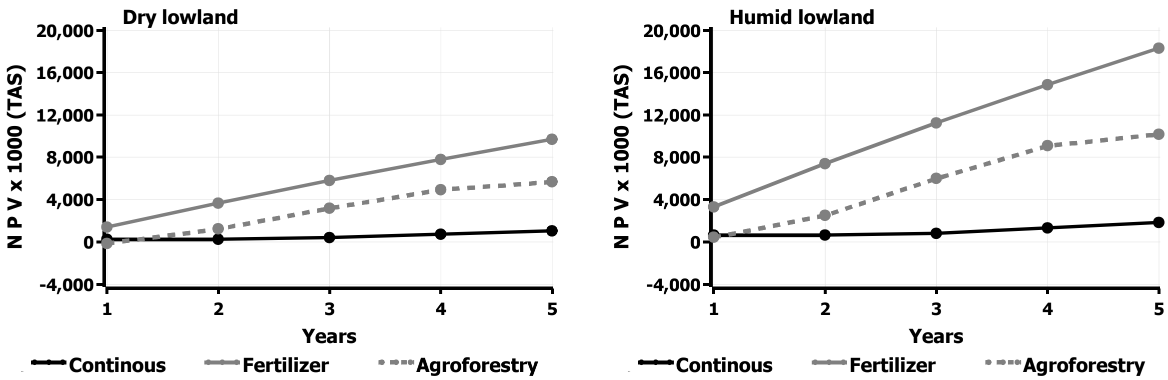


Figure 27: Net present values for different options for maize production in dry lowland, humid lowland, windward highlands and leeward highlands within South Nguru Mountains Landscape in Mvomero district

In addition, application of inorganic fertilizers is more profitable than agroforestry and continuous cropping systems across all agro-ecological zones. At the fifth year, NPV per acre of maize under agroforestry for humid lowlands, dry lowlands, humid windward highlands and sub-humid leeward highlands were 10 000 000, 6 000 000, 3 000 000 and 3 000 000 Tanzania shillings, respectively. Corresponding NPV under application inorganic fertilizers were 18 000 000, 10 000 000, 4 000 000 and 4 000 000. The financial analysis results correspond to land suitability evaluation for maize presented in section 4.2.1.1 that suggested confinement of maize production in the humid and dry lowlands. Although household surveys show that maize is the dominant crop across the entire landscape, farmers in the highlands villages had not adopted any farm management practice to counteract the effects of the limiting factors (Ziadat and Sultan, 2011). The implication is that farmers have not been able to make rational decisions regarding crops to be grown in different agro-ecological niches, which may reduce their production efficiencies and ultimately hinders efforts to move out of poverty.

These results correspond to Tenge and Hella (2005) who found poor maize performance in highlands of west Usambaras. However, our results are different from Tenge and Hella (2005) in that we did not encounter negative NPV except first year of agroforestry cropping system as opposed to negative NPVs up to three years reported in their studies. Our innovative agroforestry system that integrate less competitive soil improving shrubs that ensures increased crop yield starting from the first year of production (Ngegba et al., 2007; Odhiambo et al., 2010) may explain the observed differences. Additionally, maize profitability under inorganic fertilizer application and agroforestry cropping systems in the lowlands conform to results by Franzel *et al*. (2004). In their study, they reported favourable economic performance for production of maize under fertilization and agroforestry in dry lowlands of Tanzania and Zambia. Furthermore, it is worth noting that **valuation of benefits from agroforestry cropping system in this study did not consider fuelwood and fodder as additional valuable products from the system. Therefore, in the actual sense the NPV for the system is likely to be higher than what has been presented in this study.**

4.5.2. Maize production under combination of agroforestry and fertilizer application

Pattern of NPVs for maize production from combination of fertilizer application and agroforestry production system is presented in Figure 28. Results showed that combining agroforestry and inorganic fertilizer application is more financially attractive in the humid and dry lowlands than in the highlands. For both humid and dry lowlands, combining inorganic fertilizer and agroforestry greatly increased the NPV by about 100% compared to agroforestry alone. However, **the increase due to combined inorganic fertilizer and agroforestry with respect to inorganic fertilizer alone was only slightly improved in the humid lowland (about 11%) or unchanged in dry lowlands.**

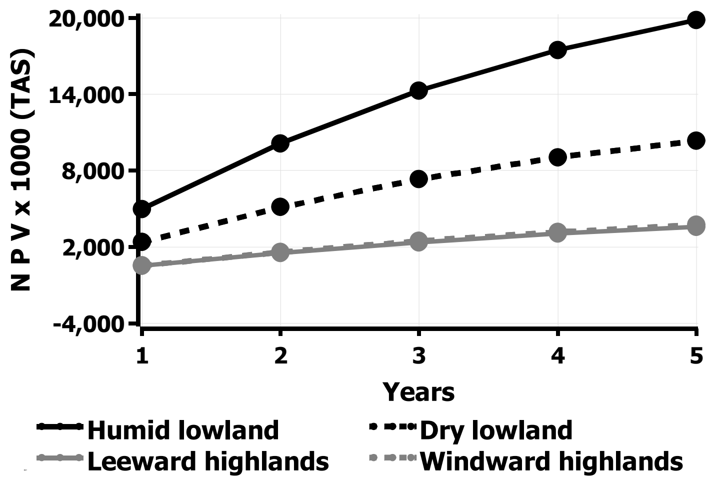


Figure 28: Net present values for maize production under agroforestry with fertilizer application in dry lowland, humid lowland, windward and leeward highlands within South Nguru Mountains Landscape in Mvomero district

Despite the insignificant difference in profitability of the sole inorganic fertilizer application against combining agroforestry with inorganic fertilization in the short- and medium-term, the two systems are known to complement each other in the long-term. Through addition of organic matter, agroforestry has an added value of increasing and conserving soil organic matter, fodder production and fuel wood (Reeves, 1997). In addition, even when soil nutrients are in large quantities agroforestry is still important as it enhances nutrient availability, especially phosphorus (P), through complex soil chemical and biological reactions (Nwoke et al., 2004). Studies have demonstrated that, with exceptions, **fertilizer application alone suffers continuous loss of organic matter which impairs capacity of the soil to hold water and nutrients** (Batiano et al., 2008). Similarly, woody perennial legumes in agroforestry can increase N fertilizer use efficiency up to two folds compared to efficiency in fertilizer alones (Kamanga et al., 2001 cited by Akinnifesi et al., 2007), which means **under agroforestry the conventional fertilizer doses can be reduced by half without affecting potential levels of production**.

4.5.3. Beans

Overall, the NPV analysis revealed that beans production is financially more attractive in the dry lowlands than in other agro-ecological zones. However, beans production was generally profitable across the entire landscape (Figure 29). In all cases, beans production were similar and more financially attractive when grown under either agroforestry or fertilizer application compared to traditional continuous cropping system. The NPV at the fifth year were about 8000, 3900, 3900 and 5000 million Tanzanian shillings for inorganic fertilizer application in the dry lowland, humid lowland, leeward sub-humid and windward humid highlands, respectively. The matching NPV for beans production under agroforestry cropping system were about 7900, 3800, 3800 and 4100. These results are in harmony with the biophysical land suitability analysis that identified dry lowland areas of Mziha, Kanga , Bwage, et cetera, as the most suitable areas for beans production than the rest of the landscape (Figure 29).

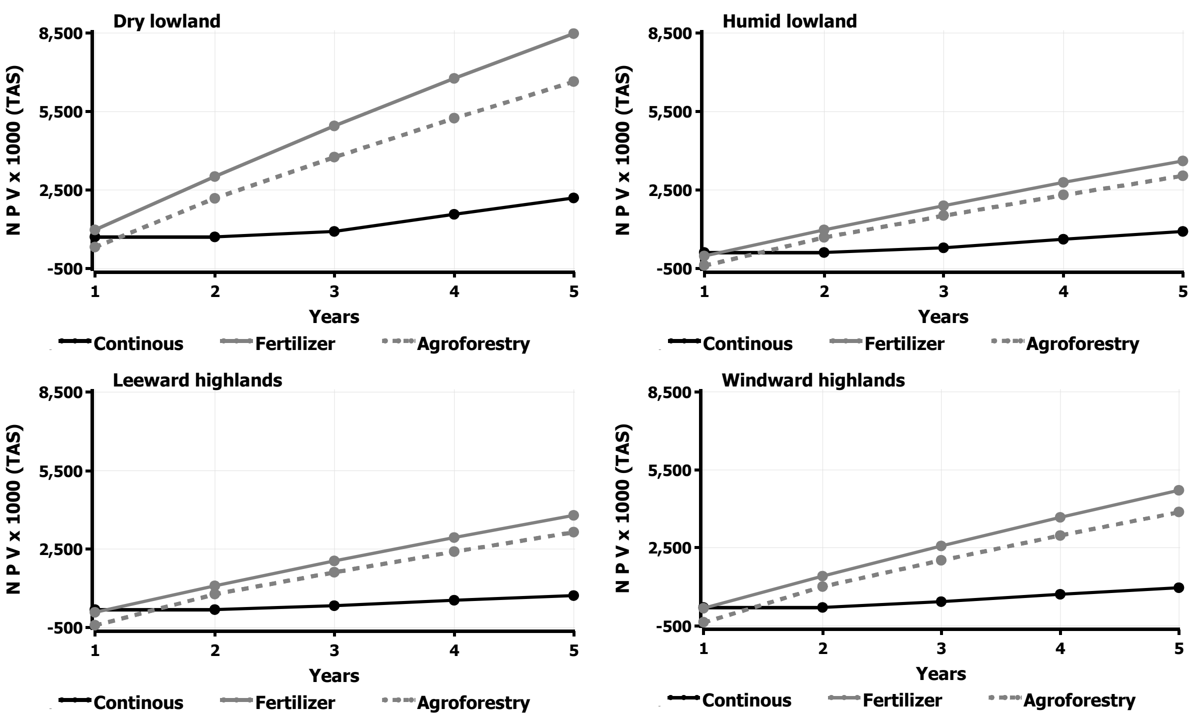


Figure 29: Net present values for different options for beans production in dry lowlands, humid lowlands, windward and leeward highlands within South Nguru MountainsLandscape in Mvomero district

4.5.4. Rice

Rice is grown in humid and dry lowland and valley bottom in the foot of highlands. Production of rice under continuous cropping versus application of inorganic fertilizers is presented in Figure 30. Application of fertilizer seems to increase profitability in studied agro-ecological zone. At the fifth year, NPV was found to range between 5 and 8 million and between 1.8 and 2.2 million under fertilization and continuous cropping, respectively. This supports the land suitability assessment, which suggested the need for application of N, P and K inorganic fertilizers for sustainable rice cultivation in the landscape. Nevertheless, results from group interviews revealed that the majority of the rice farmers do not use fertilizers due to lack of capital and inherent inadequate administration of the national agriculture input voucher scheme (NAIVS).

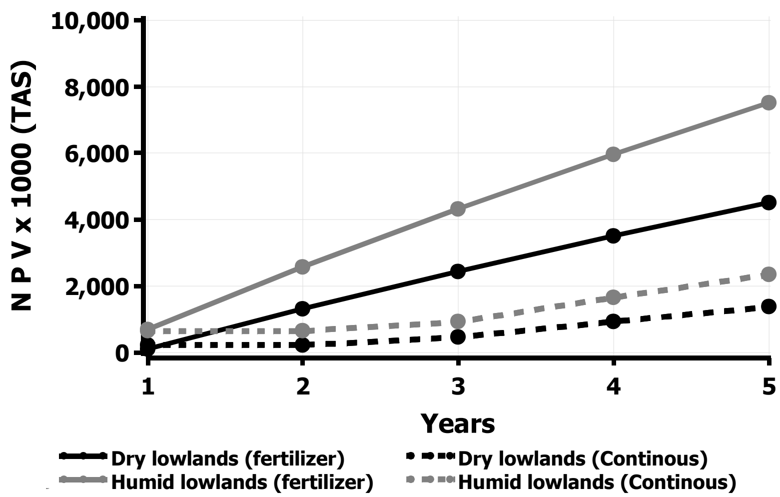


Figure 30: Net present values for production of rice under continuous and with fertilizer application per acre in humid and dry lowlands within South Nguru MountainsLandscape in Mvomero district

The NPV reported here assumes that there was a direct cost of for example labour for land preparation, tending harvesting etc. This may explain why farmers are motivated to continue cultivating rice given the low NPV found in this study.

4.5.5. **Tomatoes**

Under the current farming practices, tomatoes are grown in all ago-ecological zones in the South Nguru Mountains Landscape. However, productivity and therefore profitability varies from one agro-ecological zone to another. Financial analysis show that profitability from tomato production is highest in leeward highlands and least in humid lowland. In addition, the results show that profitability under fertilizer is significantly higher compared to continuous cropping with no input to soils (Figure 31).

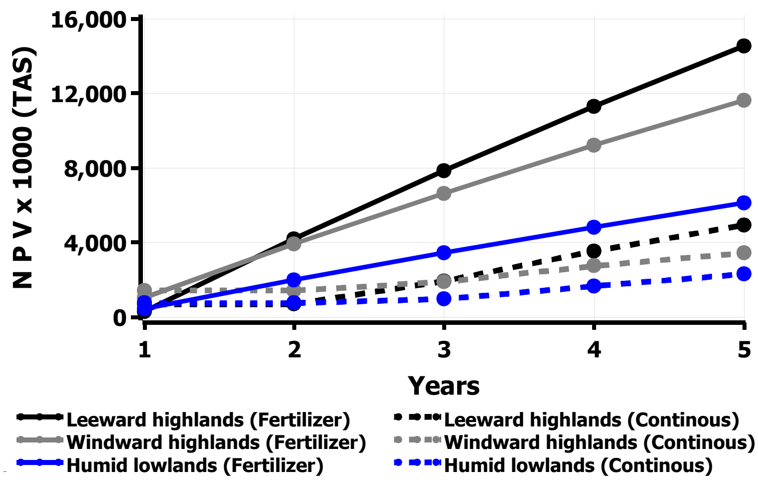


Figure 31: Net present values for production of tomatoes per acre under continuous and fertilizer application in leeward and windward highlands, and humid and dry lowlands within South Nguru Mountains Landscape in Mvomero district

These results are comparable to biophysical land suitability analysis that found tomato production to be most appropriate in relatively dry highlands than humid highlands or valleys.

4.5.6. Sunflower and sesame

Results form group interviews showed that sunflower and sesame were uncommon in highlands. Figure 32 and 33 show NPV for production of sunflower and sesame, respectively.

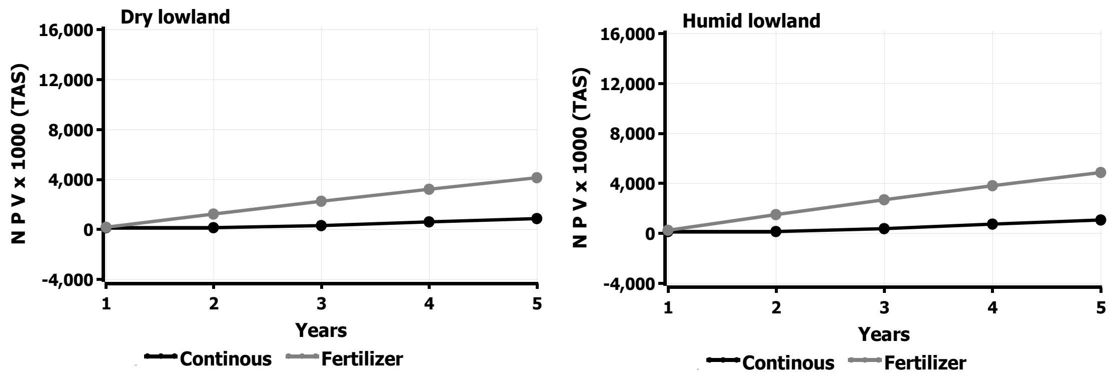


Figure 32: Net present values for production of sunflower per acre in humid and dry lowlands within South Nguru Mountains Landscape in Mvomero district

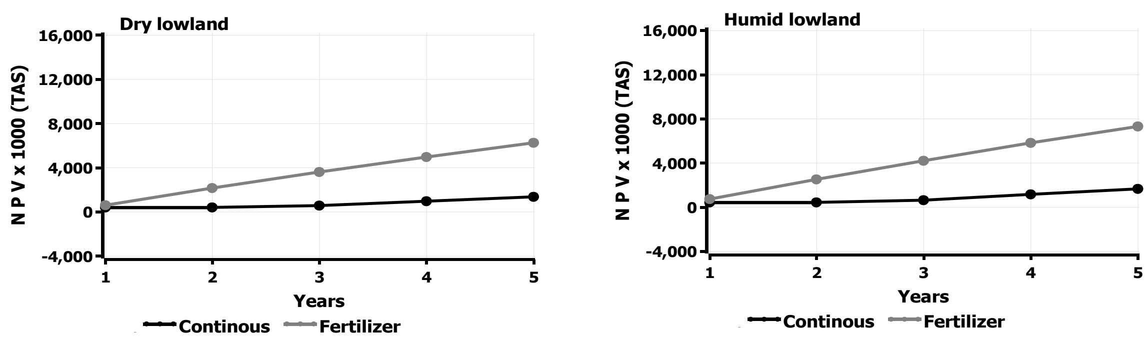


Figure 33: Net present values for production of sesame per acre in humid and dry lowlands within South Nguru Mountains Landscape in Mvomero district

Financial analysis show that production of both crops under continuous cropping either in the humid or dry lowlands is financially unattractive. For both crops, their levels of financial profitability is comparable within and between dry and humid lowlands. Application of inorganic fertilizers makes production of both sesame and sunflower significantly more attractive than continuous cropping. Therefore, application of inorganic fertilizers is the most appropriate production option for the two oily crops. However, as explained previously, combining inorganic and organic manures and retaining crop residue is recommended in order to enhance soil organic matter

4.5.7. Teak-maize and *G. robusta*-maize combinations

Financial analyses of teak-maize and *G. robusta*-maize combinations are presented in Figure 19. For the the period up to the sixth year involves intercropping of maize with either of teak or *G. Robusta*, trees. That period is characterized by low NPVs that reach to the peak at 20 and 25 years from sales of timer at the final clear felling of *G. robusta* and teak, respectively. The low profitability during the first six years is due to high investment costs associated with establishment and tending of timber trees. However, during the same period *Grevillea robusta*-maize combination is slightly profitable than teak-maize combination in the lowland due to N fixation from *Grevillea robusta* that enhances maize yields (Muthuri et al., 2005). However, in the highlands *G. robusta*-maize combination is the least profitable because of the poor performance of maize in the highlands and therefore they cannot compensate the production cost associated with *G. robusta* in the highlands compared to teak or *G. robusta* in the lowlands (Figure 34). In medium and long term, the NPVs increase as a result of sales of the produce from tree thinning and from the final tree crop harvest. It is worth noting that, in the long-run, the profitability of teak-maize is higher than *G. robusta*-maize combination due to high value of teak timber in the market. Teak-maize combination is technically possible in lowland areas while *Grevillea*-maize performs in both lowland and highland areas. It is important to note that such combinations are only possible for the non-poor and less poor households that have enough land so that they are able to cultivate maize elsewhere while waiting benefits from timber trees between the sixth and 20th or 25th years. Since maize are not profitable in the highlands, *Grevillea robusta* may also be grown in the highlands as a monoculture or intercropped with other crops such as beans and banana.

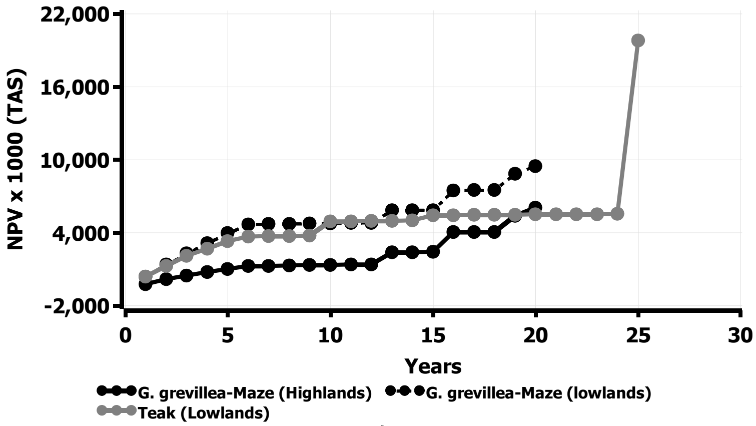


Figure 34: Net present value per acre of *Grevillea*-maize in both lowlands and highlands and Teak-maize in the lowlands assuming a rotation age of 20 years and 25, respectively within South Nguru Mountains Landscape in Mvomero district

4.5.8. Avocado-, cocoa-, mangoes- and oranges-maize combinations

Both the current practice and biophysical land suitability assessment show that mangoes can thrive in all agro-ecological zones. On the other hand, cocoa and avocado-maize perform better in the humid foothills and lowland areas; oranges can grow well in both humid to dry lowlands. NPVs for these combinations is presented in Figure 35. In all cases, trees are intercropped with maize up to sixth year. In the short-term (up 6 years), NPVs of oranges-maize and mangoes-maize is similar and tend to be highest in the lowland compared to avocado and cocoa in the highland where maize does not perform well. Above the age of six years, the variation in NPVs emanate from differences in value of produces. In this case, the system with mangoes and oranges are more financially attractive than cocoa and avocado. **The low profitability of cocoa production is likely to be due to the single buyer (Fida Hussein) who determines cocoa price**.

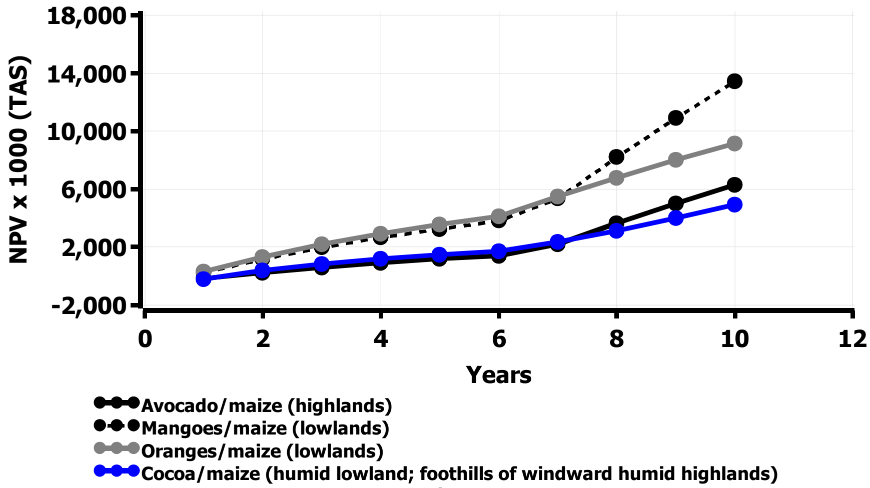


Figure 35: Net present values for intercropping of maize with each of avocado, oranges, mangoes and cocoa in different agro-ecological zones within South Nguru Mountains Landscape in Mvomero district

4.5.9. Banana-, sugarcane- and cassava-maize combinations

Figure 36 shows NPVs for banana-maize grown in humid lowland and highlands, sugarcane-maize grown in humid and dry lowlands and highlands and cassava-maize in all agro-ecological zones. Cassava, sugarcane and banana are harvested in at the beginning of second year. Maize intercropping is possible for the the first three years. Cassava-maize crops combination has the highest NPV followed by banana-maize and the least is sugarcane-maize.

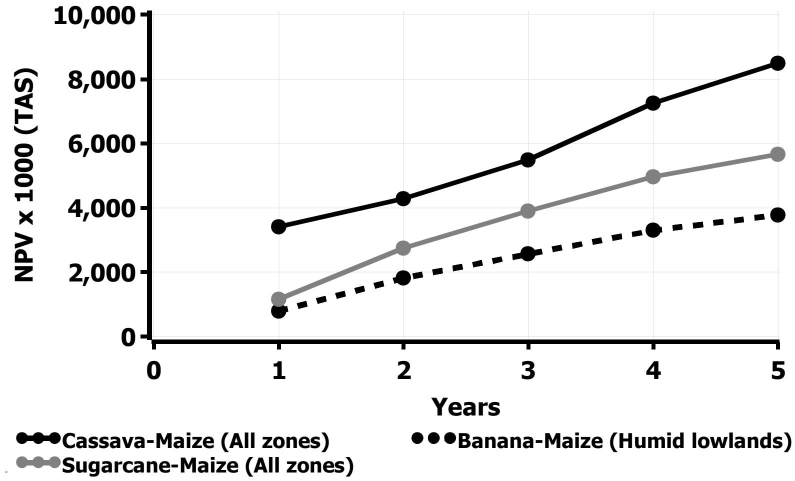


Figure 36: Net present value of banana- sugarcane- and cassava-maize combinations within South Nguru Mountains Landscape in Mvomero district

Although banana-maize combination has lower net present value, the rate of increase over time is similar to that of sugarcane-maize combination. In all cases, positive NPVs of these combinations in the first year are due to profit from intercropped maize. Otherwise, the NPV for sole banana, cassava and sugarcane would be negative for the first and second year due to high initial investment cost and late maturity. Overall, in both humid lowland and highland areas, it is more profitable to grow sugarcane than banana. However, in practice there is a trade-off between growing banana for acquiring both food and economic benefits or sugarcane for economic benefits alone.

Economic analysis of cassava maize cropping system proved to be profitable over short, medium and long term time frames (Figure 36). In poorly accessible areas such as leeward and windward highlands, cassava is mainly grown for food. In easily accessible areas found in the lowland such as humid and dry lowland, which are close to main market places (Madizini, Mvomero), cassava may be grown for sales. In that scenario cassava may be more profitable compared to banana-maize or sugarcane-maize combinations as shown in Figure 36.

4.5.10. Maize-*Tephrosia* combination in rotation with sunflower or sesame

Since both sunflower (Lindström et al., 2006) and sesame (Shapo and Adam, 2008; Alam et al., 2011) are sensitive to light competition, agroforestry practice that involve any of these crops ought to use less competitive shrubs such as *Tephrosia* or *Crotolaria* wgile avoiding deep shading trees. Figure 37 present NPVs for maize-*Tephrosia* in rotation with sunflower and maize-*Tephrosia* in rotation with sesame, respectively. All analyses are based on humid and dry lowlands because both sunflower and sesame do not perform well in highlands.

Comparison of NPVs of rotation cultivation of maize-*Tephrosia* in rotation with sunflower or sesame, and sunflower and sesame with or without inorganic fertilizer application in different agro-ecological zones is presented in Figure 37. Financial analyses show that the systems are profitable in both dry and humid lowlands. However, profitability is high in humid lowland than dry lowland.

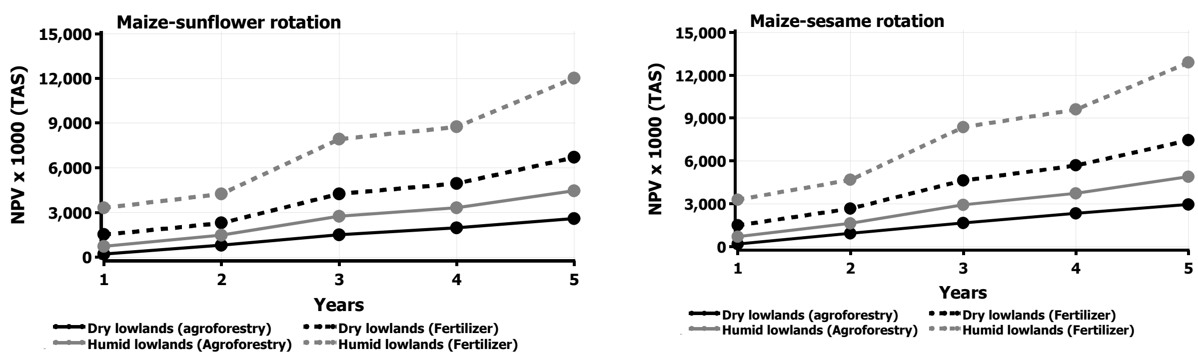


Figure 37: Net present value of maize-*Tephrosia* in rotation with sunflower, maize-*Tephrosia* in rotation with sesame, and sunflower and sesame with inorganic fertilizers cropping systems within South Nguru Mountains Landscape, Mvomero district

In both agro-ecological zones, whether sunflower or sesame is used the pattern in overall NPV for the system is always positive and virtually unchanged. Thus, the system is recommended for both agro-ecological zones.

4.5.11. Maize- and beans-cocoyam agroforestry systems

As revealed from participatory analysis of deforestation problem, encroachment of the forest reserves within South Nguru Mountains Landscape for production of cocoyams is one of drivers of deforestation in the South Nguru Mountains Landscape. As noted by (FAO, 2003a), farmers are forced to intrude forest reserves to grow cocoyams in an attempt to earn their livelihoods. In the process, they do selective felling of most trees in the forest reserve to create intermittent shade (Reyes et al., 2005; Reyes, 2008) in order to utilize the virgin land with ample soil moisture, less compacted soils with high nutrient and organic matter contents which favour growth of shade tolerant cocoyams (Nounamo and Yemefack, 2000; Pouliot et al., 2012). After four consecutive years of cocoyam cultivation the soils are exhausted and farms are abandoned and new farms open, and the cycles continues like that thereby; extending deforestation in the landscape.

Apparently, profitability and market forces represent significant hurdles against efforts to alleviate forest encroachment or deforestation due to cocoyam production. For example, field observations and focus group discussions revealed that cocoyam is among the crops with ready market in the South Nguru Mountains Landscape. Normally buyers buy cocoyam from the villages (Plate 1) as opposed to other crops which may need to be transported to Madizini or other market centres. Analyses by Angelsen et al. (1999) and Andreoni and Levinson (2001) suggest that **promotion of alternative sustainable farming technologies for cocoyam production hold the potential for resolving the issue**.

Plate 1: Young boy standing close to the pile of cocoyam collected by traders at Pemba village in Mvomero district, Tanzania

Studies have reported successful production of cocoyam outside the forests through sustainable farming practices such as application of organic manure which improve soil structure, organic matter, nutrient supply and soil moisture retention (Adeleye et al., 2010). Equally, mature agroforestry systems has been proven to create the same soil and environmental conditions that favour production of cocoyams (Reyes, 2008; Bullock et al., 2011). The suitability of agroforestry for cocoyam production is due to intermittent shade provided by trees (Reyes, 2008; Pouliot et al., 2012), improved soil nutrition through N fixation and organic matter via tree litters (Ernest et al., 2004). In this study, maize- and beans-cocoyam agroforestry systems are analysed to serve as an ex-ante evaluation for the possibility to replace the current cocoyam production practice with a more sustainable agroforestry practice.

A modified rotational woodlot agroforestry system is proposed for sustainable production of cocoyam. The proposed woodlot agroforestry system involves two distinct phases; the first phase is characterised by intercropping of maize or beans together with less competitive soil improving shrubs (e.g. *Tephrosia vogelii*) and coppicing leguminous trees such as *Albizia versicolor* and *Gliricidia sepium*. The first phase is terminated after about five years when trees begin to limit growth of intercropped maize or beans due to excessive shading. At this stage, shade tolerant cocoyam is introduced to replace maize or beans for another successive five years before trees are clear felled to begin another cycle of maize or beans intercropped with tree coppices in association with one of less competitive soil improving shrubs. Apart from shade, cocoyam benefit from organic matter built up during the first phase, which is needed for optimum growth. Therefore, the proposed agroforestry system is analyzed as an alternative to the current destructive practice of cocoyam production in South Nguru Mountains Landscape. The practice involves selective felling of trees to create intermittent shade suitable for optimum cocoyam growth. Thus, the analysis here serves as an ex ante evaluation for the possibility to replace the current cocoyam production practice with a more sustainable agroforestry practice.

Figure 36 presents financial analysis for the maize- and beans-cocoyam agroforestry system over a period of ten years. **The analyses exclude dry lowland agro-ecological zone in which cocoyam do not grow well**. Overall, both maize- cocoyam agroforestry and beans- cocoyam agroforestry systems result in positive NPVs suggesting their overall economic viability.

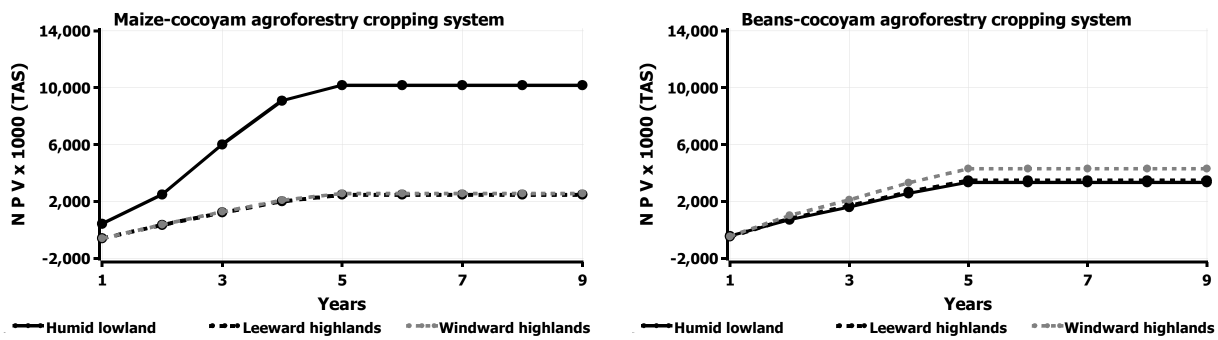


Figure 38: Net present values of maize-and beans-cocoyam agroforestry production systems within South Nguru Mountains Landscape, Mvomero district

Results from the present study suggest that NPVs are influenced by interaction between the first crop (whether maize or beans) and agro-ecological zone. In the humid lowland, maize-cocoyam system came out as an outstanding possibility with NPV of 9,000,000 Tanzania shillings compared to 3,000,000 from beans-cocoyam system at the same time horizon. The same system yields similar but lowest corresponding NPV of 2,000,000 Tanzanian shillings in either leeward sub-humid or windward humid highlands. On the other hand, the differences between agro-ecological zones are negligible for beans-cocoyam agroforestry system, which yields NPVs of 4,000,000, 3,500,000 and 3,000,000 Tanzania shillings at tenth year in windward highland, leeward highland and humid lowland, correspondingly. Therefore, the maize-cocoyam agroforestry system is the most profitable option in the humid lowland whereas beans-cocoyam agroforestry is profitable in both leeward and windward highlands.

Of paramount importance is a note on the sustainable alternative technology for cardamom production in the South Nguru Mountains Landscape. Menegon et al. (2008) noted intercropping of cardamom and cocoyam in encroached areas within the forest reserves at higher altitudes (>800 m asl) of the Nguru South Mountains Landscape. Reyes et al. (2006) attributed cardamom cultivation as the major cause of forest conversion in the East Usambaras, where it is intercropped with cocoyam after forest clearance. This implies that the biophysical requirements for cardamom are similar to those of cocoyam (Korikanthimath, 2001). Thus, cardamom can be grown together with cocoyam on the windward humid highlands during the second phase of the proposed woodlot agroforestry system. Based on Bullock et al. (2011) **introduction of cardamom in the agroforestry system is known to be financially attractive**.

Use of coppicing tree species in the agroforestry system proposed in this study makes it superior than the one described by Bullock et al. (2011). Coppicing agroforestry tree species produce large amounts of high-quality biomass with high nitrogen content and low contents of lignin and polyphenols, thereby contributing to relatively higher soil improvement than non-coppicing tree species (Mafongoya et al., 1998; Chikowo et al., 2004). Besides, coppicing trees need to be established only once and can then be used for many years (over 24 years) without replanting (Nyamadzawo et al., 2012). Nevertheless, inclusion of cardamom (described as a heavy nutrients feeder) in the system will require addition of at least half dosage of mineral fertilizers to complement soil improvement effects from coppicing agroforestry trees.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

On the basis of other studies on biophysical requirements of different crops and biophysical assessment conducted in the South Nguru Mountains Landscape the study has identified biophysically suitable crops/crop combinations for different parts of the landscape. Sixteen major land utilization types namely; smallholder low input rain-fed maize, banana, beans, cocoa, cowpea, rice, sesame, mango, citrus, cassava, sunflower, tomato, *Grevillea robusta*, teak, avocado and cardamom provided by the client were evaluated. The matching of crops/crop combinations requirements and existing biophysical features of the landscape resulted in a clear spatial distribution of the potential crops/crop combinations corresponding to spatial distribution of the various mapping units in the South Nguru Mountains Landscape. In most cases biophysical features vary greatly within and between village and most villages have multiple mapping units. Therefore, the resultant spatial distribution of the potential crops/crop combinations does not necessarily coincide with village boundaries. The best practice to use the report should be guided by different maps that depict spatial distribution of the different crops/crop combinations rather than sticking to village boundaries. Annex 10 provides a summary of biophysically and financially viable crops/crop combinations for different parts of the landscape. Furthermore, steep slopes with shallow soils and low organic matter content is the major factor that limit production of most crops in the humid and sub-humid mountainous areas of the Eastern and Western parts of the landscape.

The current continuous cropping without any inputs is not only environmentally destructive but also financially unattractive. However, with low opportunity cost of labour and limited asset endowments the poor and poorest are forced to continue with the less paying continuous cropping. Application of inorganic fertilizers is always more financially attractive than agroforestry. **Combining inorganic fertilizers and agroforestry is more productive and profitable**, and has an added advantage of minimizing negative fertilizer impacts on the environment. It is worth noting that, due to paucity of data financial analyses did not consider additional benefits from agroforestry notably wood production, carbon sequestration and fodder production. Furthermore, agroforestry has the potential to reduce the pressure on adjacent forest reserve thereby contributing to enhancing capacity of the reserved forests to supply environmental services including conservation of biodiversity, carbon sequestration and maintenance of water flow.

The financial attractiveness of most climate smart agricultural options analysed, highly positive attitude towards environmental conservation, and perceptions that poor farming practices are the immediate causes of deterioration of land, forest and water resources; are promising factors for adoption of climate smart agricultural options. However, **the fact that majority farmers in the South Nguru Mountains Landscape are poor and poorest is likely to hinder adoption of most climate smart agricultural practices such as inorganic fertilizers, agroforestry, avocado, orange, mango, *Grevillea robusta* and teak trees due to the associated high investment costs**. Besides, although farming of trees such as *Grevillea robusta* and teak is financially attractive, **small land holding for majority of the farmer in the South Nguru Mountains Landscape is likely to limit wide adoption of the practice**.

Cocoyam and cardamom are among the most profitable crops currently grown in many villages in the humid and sub-humid highlands agro-ecological zones and foot hills of the humid lowlands. However, farmers are forced to encroach the forest reserve in search for shade microclimate and good soils with high organic matter needed for better growth of the crops. This raises concern over forest conservation as encroachment is now ranked among the most important causes of deforestation in the South Nguru Mountains Landscape.

The current sources of agricultural produce price information are farmers-to-farmer or relying on information conveyed through buyers. A notable feature is that as you move away from town centres the tendency to rely on buyers for information increases and vice-versa. The implication of this situation is that buyers are likely to take advantage of the ignorance of the farmers to dictate very low prices for agricultural produce, which has negative impacts on farmers’ income. The situation is more adverse in remote villages such as Kinda, Mndela and Kimaguru villages than easily accessible villages such as Digoma, Mkindo and Bwage villages. Given the fact that most of the villages in the Nguru South Mountains Landscape have access to mobile phone network there is very high potential for use of mobile phone short messages system for dissemination of agriculture produce price, and/or extension information. However, investment is required to establish the mobile phone information system apart from recurrent operational costs. Other market-related barriers in the South Nguru Mountains Landscape are poor road infrastructure, long distance to the market places and inadequate cooperation among farmers. These factors constrain farmers’ bargaining power that results in low farm-gate prices, which has adverse impacts on their overall incomes.

5.2 Recommendations

6) Application of appropriate soil and water conservation measures including contour farming and agroforestry system such as alley cropping are recommended in order to enhance suitability of most steep slopes for crop production. Alley cropping is highly suited to humid and sub-humid highland areas with ample soil moisture. Scale-up terraces and pineapple contours that have been successfully established in Uluguru Mountains is another possible option. In addition, introduction of high value crops such as vanilla and black paper can further enhance incentive for adoption of soil water conservation measures.
7) Since the majority of the poor and poorest are keeping chicken as their valuable economic asset, it is recommended that interventions to enhance efficient chicken production be introduced in order to help them climb out of poverty. As they proceed on their way out of poverty, in the process of accumulating and trading-up assets, they are likely to improve their capability to raise the investment capital required for adoption of most of CSA options. In addition, small credit facilities can help poor farmers access investment costs required for CSA. The most appropriate credit scheme is the village and savings (VSL) scheme that is already available in localized areas within the landscape, and which has been proved to be more accessible by the poor and poorest. TFCG’s long experience with VSL is expected to provide necessary lessons to guide its scaling up.

8) It is recommended that *Grevillea robusta* and teak trees be grown in either monoculture woodlots for farmers with ample land holdings (10 acres or more) or mixed with crops for farmers with medium sized farms (3 to 5 acres). For farmers who have small land holdings (less than 3 acres), trees should be planted along farm boundaries.
9) Appropriate agroforestry systems that integrate coppicing trees with annual crops for the first five years can create suitable soils and microclimate conditions for production of cocoyam and cardamom from the sixth up to tenth years of the system before trees are cut to start the cycle afresh with coppice regeneration.

10) Establishments of mobile phone based market information system can help the farmers to access relevant agricultural produce price information to enhance their bargaining powers. Besides considerable initial investment cost, such a system will require establishment of farmers cooperative to manage the communication system. The cooperative can also be an organ to voice for farmers better deal in the market system, and/or demanding their rights from the government. Forming an apex of the network of village and savings and loan groups may be one option for such a cooperative. Furthermore, encouraging farmers to use Eastern Arc Mountains Conservation Endowment Fund (EAMCEF) can help to resolve the most of the funding issues for community based initiatives.

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ANNEXES

Annex 1: Terms of reference for the consultancy on climate smart agriculture options for small-scale farmers in the South Nguru Mountains landscape, Mvomero District, Morogoro

1. Introduction

1.1 Background information

Since January 2013, the Tanzania Forest Conservation Group (TFCG) in collaboration with the Community Forest Conservation Network of Tanzania (MJUMITA), the Tanzania Forest Services (TFS) and Mvomero District Council (MVDC), have been implementing the project *"Adding Value to the Arc: Forests and Livelihoods in the South Nguru Mountains".* The project is being implemented in 34 villages in Mvomero District, Morogoro region. The five-year project is funded by the European Union.

The goal of the project is to alleviate poverty and improve economic resilience among marginalised rural communities in Mvomero District, Tanzania. The specific objective of the project is to strengthen participatory forest management and sustainable economic development around the South Nguru Mountains. The project will achieve its objectives through five key results:

Expected Result 1: Community-level institutions and district authorities exercising legislated rights and responsibilities for management of forest resources on village land;

Expected Result 2: Community-level institutions and central government agencies exercising legislated rights and responsibilities for co-management of forest resources within central government reserves;

Expected Result 3: Conservation-compatible enterprise opportunities developed at community level;

Expected Result 4: Capacity of government institutions to implement forest management enhanced;

Expected Result 5: Project impacts objectively measured, verified and attributed, and experiences synthesised and communicated.

As part of Expected Result 3, the project plans to support small-scale farmers to adopt climate-smart agricultural and agroforestry techniques that will improve livelihoods; enhance climate change resilience and contribute to climate change mitigation. Building on TFCG's experience elsewhere in Tanzania, a site-specific agricultural strategy is being developed. This consultancy will provide inputs to the development of the strategy. The findings of the consultancy will be presented to farmers as a basis for selecting crops to be cultivated by farmer field schools.

2. Environmental and Socio-economic Context

The South Nguru landscape is globally important for the conservation of biodiversity due to high levels of species endemism. The landscape is also important for carbon sequestration and storage; and comprises part of the catchment area for the Wami River that supplies water for domestic use; and for large and small-scale irrigation in Morogoro and Coast regions. Most of the remaining forest lies within the boundaries of Mkingu Nature Reserve and Kanga Forest Reserve, both managed by Central Government. Some patches of woodland and forest also remain on village land.

Deforestation rates are high within the landscape. Even within the Central Government reserves the annual deforestation rate has reached 0.81% and 0.17% for Mkingu Nature Reserve and Kanga Forest Reserve respectively. The rate is significantly higher outside of the reserves. The main deforestation driver is agriculture. Charcoal production and un-planned timber harvesting also contribute to both deforestation and forest degradation.

Most farmers practice traditional agriculture including shifting cultivation. The main crop throughout the landscape is maize. Rice is also commonly cultivated in the lowlands as well as sugar cane for villages close to the Mtibwa sugar estate; and beans and sesame in other lowland areas. In the highlands, bananas and yams are commonly grown, as well as cocoa and cardamom in some highland villages. Few farmers use improved varieties or other agricultural inputs. At least ten village or ward agricultural officers are in place within the project villages; however most lack resources to visit farmers and conduct training events.

In terms of climate change, climate models (see www.climatewizard.org) based on a medium emission scenario predict an increase in annual average temperatures of around 1.5° c over the next 50 years in the South Nguru landscape, whilst high emission scenario models predict an increase of up to 3° c. In terms of precipitation, models predict higher precipitation from September – May with hotter, drier dry seasons from June – August. Given that most farmers in the South Nguru Mountains, practice rain-fed agriculture, these changes will require farmers to adapt their current practices.

Climate smart agriculture aims to achieve the triple wins of poverty alleviation; climate change adaptation; and climate change mitigation. It embodies a suite of agricultural approaches including conservation agriculture and agroforestry. The Adding Value to the Arc project aims to integrate more sustainable production with the Making Markets work for the Poor approach (M4P) whereby farmers are empowered to have more control over their role in the market. This includes building producer business skills; supporting value chain innovations; building their negotiating and advocacy capacity; and entering into new markets.

3. Scope of work

3.1 Objectives of the consultancy

The objectives of the consultancy are:

- To provide accurate, well-referenced data on the potential of different crops/crop combinations to contribute to improved livelihoods and enhanced climate change resilience for small-scale farmers living in the South Nguru landscape.
- To provide a clearly articulated comparative analysis of the relative profitability of different crops to small-scale farmers living in different zones of the South Nguru landscape.
- To review agricultural product price information systems potentially available to small-scale farmers in Mvomero District; and other value addition initiatives or innovations.

- To identify market-related barriers facing small-scale farmers in the South Nguru landscape and to make recommendations on interventions that the project could support in helping farmers to overcome those barriers.

3.2 Scope of the consultancy

The consultancy will provide clearly-referenced, well-substantiated data and analysis in relation to 16 crops most of which are already cultivated within the South Nguru landscape. The crops to be included in the comparative analysis are:

1) Maize
2) Rice
3) Beans
4) Sesame
5) Cowpeas
6) Sunflowers
7) Bananas
8) Cocoa
9) Cardamom
10) Tomatoes
11) Cassava
12) Mangoes
13) Oranges
14) Avocado
15) Teak
16) *Grevillea robusta*

In the context of these crops the consultants will report on the following:

a. The Biophysical profile of the area

Using reliable and clearly referenced published data, including GIS data, the consultants will characterize the landscapes according to biophysical factors including soil type, slope, altitude, precipitation, temperature and proximity to water sources. This analysis will then be used to identify the crops most appropriate for farmers living in different parts of the landscape. The consultant will compile maps and descriptions of the precipitation, temperatures, soil types, hydrology and topography of the landscape for comparison with the biophysical requirements of each crop. This will be used to identify areas with high / medium / low potential for each crop.

b. Crop-specific analysis aimed at identifying optimal crops for small-scale farmers in different parts of the landscape

For each crop the consultant will provided well-referenced, up-to-date data, geographically relevant data in a consistent tabular form on the following:

i. Biophysical conditions determining the suitability of an area for a crop

The consultant will describe:

- the temperature range under which the crop will grow;
- the precipitation range under which the crop will grow;
- soil preferences;
- slope;
- irrigation needs;
- topographical preferences.

The consultant will provide a map showing the suitability of different areas across the landscape for the crop. Land will be categorised as being of high / medium / low potential for the crop based on the biophysical conditions determining suitability described above.

ii. Costs of production:

These will be considered on the basis of cultivating 1 acre of the crop under consideration for the equivalent of 1 growing season. For tree crops an indication should be provided of the costs until the first harvest; the number of years until the first harvest; and then annual costs for e.g. fruit trees.

At a minimum the Consultant shall provide cost information on:

Seeds / grafting stock / cuttings – what are the main open-pollinated varieties available and how much do they cost based on the quantity recommended for 1 acre for 1 growing season;

Other inputs – what other inputs (e.g. fertilisers, pesticides etc) are needed and / or recommended for cultivating the crop based on the recommended amount for 1 acre for 1 growing season and outlining different options such as organic and inorganic fertilisers;

Water – is irrigation required and if so, what are the costs of irrigation.

Labour – how many days labour are required for 1 growing season from farm preparation (assuming no forest clearance); to sale.

Other costs - list any other costs of production not considered here.

Availability of inputs – which inputs are available from stockists in the project area including Madizini and Mvomero.

Input subsidy schemes – description of any input subsidy schemes operating in the South Nguru landscape or Mvomero District relevant to the crop under analysis.

Cost data should be no older than 2012.

iii. Potential yields

Potential range of yields from 1 acre from 1 growing season depending on specified conditions e.g. use of improved seeds and inputs. The consultant should state clearly the conditions necessary for high / medium /and low range of yield for each crop. The Consultant will recommend the optimal combinations of improved seed varieties (OPVs) and inputs including specifying the seed varieties most appropriate for the area; and the best and / or most cost effective inputs. The consultant will also advise on crop combinations such as crops well-suited to intercropping together including tree crops. This will consider issues such as crops that are nitrogen-fixing, fodder crops, hedge / boundary crops etc. The consultant will also advise on appropriate soil management techniques for the different crops.

iv. Storage

Storage – what are the storage options for the crop and what costs are associated with the different options? For how long can these be stored realistically by small-scale farmers? This should be presented separately for different storage options. What risks are associated with storing the crop?

v. Recommended planting and harvesting months.

vi. Market profile

Main markets location / profile of the Main buyers / market structure – provide a profile of the markets for each crop including a description of the role of traders, transporters, wholesalers, retailers and buyers. Where applicable the consultant should describe different value chains e.g. local, national and international markets for crops; or government strategic reserve purchases vs. Private sector buyers.

Prices – provide prices at the farm gate; local market e.g. Madizini; Morogoro; Dar es Salaam or other main market. Prices should be cited based on clear units e.g. TZS / kg or TZS / tonne and should be comparable with the units used in describing potential yields.

The consultants should provide their observations and insights on the accessibility of the markets for small-scale farmers in the South Nguru landscape.

The consultant should describe the presence of any ongoing or planned government-led, private sector or NGO-led schemes associated with this crop.

Market data should be no older than 2012.

vii. Other risks, opportunities or barriers associated with the crop

Taking into consideration the vulnerability of each crop to disease, drought and pests; losses during storage; and market reliability and accessibility; the consultant will classify each crop as being of high / medium / low risk. For each crop the consultant will provide a justification of the risk ranking. The consultant will also describe any opportunities or potential barriers that farmers should consider in assessing the potential of the crop.

viii. Potential profit range per acre

By comparing the costs and prices listed above, the consultant will provide the potential profitability of the different crops per acre per growing season. This will be presented as a range with an explanation of the conditions most strongly influencing the profitability of a crop. This will also consider the timescale over which farmers can expect to receive a profit i.e. those that are profitable in the short (1 year), medium (2 – 5 years) and longer term (6 + years).

ix. Potential to help in climate change adaptation

Comments on how the crop will tolerate the conditions predicted for the South Nguru landscape; and the availability of CC-resilient varieties.

x. Potential to contribute to climate change mitigation

c. Comparative analysis of the relative profitability of different crops to small-scale farmers living in different zones of the South Nguru landscape.

The consultant will compare the results of the profitability and risk analysis for farmers living in different zones of the landscape.

d. Gender

The consultant will consider any factors affecting the relevance of the findings from a gender perspective.

4. Final report structure

Title page

Executive summary

This will provide a concise, well-articulated summary of the methods, results, conclusions and recommendations of the consultancy. No more than 3 pages

Introduction

This will describe the objectives of the consultancy and will provide a profile of the landscape including an overview of current agricultural practices and crops in the South Nguru landscape.

Literature review

A description of the relevant, available literature.

Methods

A description of the data collection methods used by the consultants including a list of people interviewed and reports and publications that were referred to (these may be included in the Appendices).

Results

Biophysical characterisation of the area. This will include sections on soil, topography, precipitation, temperature and hydrology. Each section will include at least one map showing the relevant conditions in the South Nguru landscape overlain with the village boundaries. Each section will include a description of the values presented. For example the section on soils will describe the main characteristics of the soil types present in the landscape in the context of their suitability for different kinds of agriculture. The sections on precipitation and temperature will describe temporal and spatial patterns for the landscape

Crop profiles

This will include separate sections for each of the 16 crops. For each crop, results will be presented in a consistent tabular format based on the ten factors listed in section 3.2 b of this scope of work.

Discussion

This will include a clearly articulated comparative analysis of the profitability and risks of different crops or crop combinations for farmers living in different parts of the landscape.

Comparisons should be made in table form wherever possible. The analysis should be well-substantiated and should link back to the results section.
This section will also present the consultants findings on any gender-related issues.

Conclusions

Recommendations

Detailed recommendations targeting the project implementers, small-scale farmers and Mvomero District council. Recommendations should be well-substantiated, specific and relevant.

List of references

References should be listed and if relevant the website where the source can be downloaded, should be provided.

Annexes

The terms of reference

List of people consulted

6. Deliverables

a) 1 inception report detailing the approach to be used. This will be submitted to TFCG within 5 working days of the start of the consultancy
b) 1 technical report following the format described above.
c) Data files

Annex 2: List of people consulted

S/N.	Full name	Institution/village
1	Hassan Chikira	TFCG AVA Project
2	Hamis Masinde	TFCG AVA Project
3	Boniface Laiton	TFCG AVA Project
4	Fatma Rashidi	TFCG AVA Project
5	Raymond Nlelwa	TFCG AVA Project
6	Sylvia M. Kalembeka	TFCG Dar
7	Charles K. Meshack	TFCG Dar
8	Tadeus Macha	DED Mvomero
9	K. O. Mdule	DED Mvomero
10	Foya Hozeniel	DED Mvomero
11	Winfrida Kavishe	DED Mvomero
12	Mohamed Malekela	DED Mvomero (Driver)
13	Abeid Kindo	MKINDU NATURE RESERVE
14	Mwajuma Mkinga	Msolokelo village
15	Ally Shaban	Pemba village
16	Shaban Omary	Masimba village
17	Asha Juma	Masimba village
18	Restituta F. Masawe	Kanga village
19	Leah Benedict	Mziha village
20	Joyna Clement	Kisimagulu village
21	Yustina Rajabu	Dihombo village
22	Aloyce Mchanja	Kinda village
23	Gelali N. Kalatitu	Maskati village
24	Paulo J. Mwenyas	Maskati village
25	Zahoro Sekilindi	Kigugu village

Annex 3**:** Checklist for focus group discussion and key informant interviews

Objectives
To gain understanding on issues related to:
Key crops and farming practices, and other livelihood activities; their linkage to and impacts (positive or negative) on land, forest and water resources
Existing market and market relations, and opportunities for upgrading communities within the value chain
Experience and lessons from previous agriculture and natural resources conservation projects

Participants
Focus group discussion: Two separate sessions with local leaders: i) Village Chairperson, Village Executive Officer, Chairperson of Village Natural Resources Management Committee, Community Coaches, Extension officer, influential person, knowledgeable elderly man and woman, youth etc (Maximum of ten);

Key informants: Ward Executive Officers and Councillors/District Community development Officer

The process
Use the checklist below to elicit discussions

PART 1: AGRICULTURAL PRODUCTION

Costs involved of crop production

Crop	Since when have you been growing the crop?	Labor for land preparation [Man-days]/acre		Cost for cultivation using a tractor/acre	Cost of seeds/planting materials/acre	Purchase of fertilizers during sowing/acre	Labor for sowing/planting [Man-days]/acre	Labor for fertilizer application during sowing [Man-days]/acre		Labor for weeding [Man-days]/acre			Purchase of fertilizers after sowing/acre	Labor for fertilizer application after sowing [Man-days]/acre		Labor for harvesting [Man-days]/acre
		Year 1	Year 2 - 15	Year 1 – 15	Year 1 - 15	Year 1 - 15	Year 1 - 15	Year 1	Year 2 - 15	1^{st} weeding	2^{nd} weeding	3^{rd} weeding	Year 1 - 15	Year 1	Year 2 - 15	Year 1 - 15
1. Maize																
2. Rice																
3. Beans																
4. Sesame																
5. Cowpeas																
6. Sunflowers																
7. Bananas																
8. Cocoa																
9. Cardamom																
10. Tomatoes																
11. Cassava																
12. Mangoes																
13. Oranges																
14. Avocado																
15. Teak																
16. Grevillea robusta																
17. Cocoa																

Is land hiring common in this area? What is the cost of hiring 1 acre in this area?
How much does it cost to purchase the following farm implements in different locations shown in the Table[7]?

Type of implement	Dumila	Turiani/Madizini	Mvomero	Morogoro
Hand hoe				
Matchet				
Fertilizers				
Herbicides				
Insecticides				
Manure				

How much does an acre yield (Min. and Max.) for each of the following crops?
Maize, rice, bean, Sesame, Cowpeas, sunflowers, Bananas. Cocoa, Cardamom, Tomatoes, Cassava, mangoes, Oranges, Avocado, Teak, *Grevillearobusta*

What are the common tree species grown in this area for different purposes?

Tree species	Uses [Tick (√) the respective uses]					
	Timber	Fruits	Intercropping	Medicine	Fodder	Building poles

What are the common means of transporting harvested crops to the market places?
Apart from farming, what are the other common economic activities in this area?

PART 2 MARKETING AND MARKETING RELATIONS

What are different market places for the following produces? Who are the actors involved?
Maize, rice, bean, Sesame, Cowpeas, sunflowers, Bananas. Cocoa, Cardamom, Tomatoes, Cassava, mangoes, Oranges, Avocado, Teak, *Grevillearobusta*
For different market places mentioned, what are costs incurred during the marketing of the following produce?
Maize, rice, bean, Sesame, Cowpeas, sunflowers, Bananas, Cocoa, Cardamom, Tomatoes, Cassava, mangoes, Oranges, Avocado, Teak, *Grevillearobusta*
Who are the actors in marketing of each of the crops grown in this area? What are the roles for each of the marketing actors?
What are the key agricultural inputs for each of the crops grown in this area and how and where do you obtain them?
Are you aware of any input subside program in this area? When did it start? How does it work? How useful is the system? What are the successes, and failures of the existing input subside program in this area?
If the subside for agricultural inputs exists, is there any particular group of people (or even certain individuals) who have systematically failed to take the opportunity subsidized inputs? Is this pattern socially acceptable or something that needs to be addressed? What could be done to help the disadvantaged social groups begin to engage in productive uses of water?
What are the marketing challenges and how do you cope with them?
What are the means of accessing crop prices information? Are the means useful?

[7]Need to check the prices from respective stockists selling agricultural inputs in respective areas

What are the common means of adding value to the following crops for marketing?
Maize, rice, bean, Sesame, Cowpeas, sunflowers, Bananas, Cocoa, Cardamom, Tomatoes, Cassava, mangoes, Oranges, Avocado, Teak, *Grevillearobusta*
Who are involved in value addition for each of the crops grown in this area?
What are common ways of storing following harvested crops?
Maize, rice, bean, Sesame, Cowpeas, sunflowers, Bananas, Cocoa, Cardamom, Tomatoes, Cassava, mangoes, Oranges, Avocado, Teak, *Grevillearobusta*

PART 3: ENVIRONMENTAL ISSUES

What are the common environmental challenges[8], related to land, forest and water resources; in your area and how do you cope with them?
What has been the trend in soil fertility and yields of each of the crops grown over the last 15 years?
If the soil fertility is decreasing, what are you doing to address the problem?
Is soil erosion common in your area?
How do you address the problem of soil erosion?
What are the soil and water management practices commonly used in this area (soil and water conservation – rainwater harvesting, conservation tillage)?
What/when are the major growing seasons for each of the crops grown in the area? Provide calendar of key farming activities regarding each of the crops grown in this area

[8]Note the challenges to be included in the problem analysis exercise to be done later in the afternoon session

Annex 4: Household Questionnaire for Situational Analysis of the Potential Climate Smart Agriculture Options in South Nguru Mountains Landscape

SECTION 1: GENERAL INFORMATION

1. Name of interviewer………………………… 2. Date of interview………………………..
3. Division……………………………………… 4. Ward ………………………………
5. Village ……………………………………… 6. Sub-village……………………..

7. Wealth category: (*Tick where appropriate)*

Status	[Tick (✓)]
Non-poor	
Less-poor	
Poor	
Poorest	

SECTION 2: HOUSEHOLD CHARACTERISTICS

8. Age of respondent (Years)………Where was the household head born?……………………...

9. Relation of respondent to household head…………………………………………………

10. Sex of the respondent [Tick (✓)]: 1. Male__________ 2. Female_______

11. Marital status [Tick (✓)]: a.Single___b. Married___c. Divorced__d. Widow/ Widower_____

e. Other (Specify)………………………………………………………….

12. What is your education level? [Tick (✓)]

a. No formal education_____ b. Primary education_____ c. Secondary education_

d. College/university_______ e. Other (specify)……………………………………

13. Main economic activities for the household……………………………………………

14. Household composition (only for those who live within the household, exclude those who have permanently migrated to other areas e.g. town)

Age category	Total number		
	Male	Female	Total
< 5 years			
5 to 17 years			
18 to 30 years			
21 to 60 years			
> 60 years			

SECTION 3: CROP PRODUCTION INFORMATION

15. Ask the respondent to provide information on production of crops specified in the Table for the last season

Crop	15a. Do you grow this crop? [1] Yes [2] No *(Go to next activity)*	Farm size used to grow each crop (in acres)	
		Owned	Hired
1. Maize	1 2		
2. Rice	1 2		
3. Beans	1 2		
4. Sesame	1 2		
5. Cowpeas	1 2		
6. Sunflowers	1 2		
7. Bananas	1 2		
8. Cocoa	1 2		
9. Cardamom	1 2		
10. Tomatoes	1 2		
11. Cassava	1 2		
12. Mangoes	1 2		
13. Oranges	1 2		
14. Avocado	1 2		
15. Teak	1 2		
16. Grevillea robusta	1 2		
17. Cocoa	1 2		

16. If you hired land, state the cost of hiring land per acre per season……………………….

17. What is the overall trend in crop yields over the last five years [Use Tick (✓)]?

Increased____

No change_____

Decreased____

18. Give reasons for (if applicable):

a) Increased crop yield____

b) Decreased crop yield____

SECTION 4: MARKETING OF AGRICULTURAL PRODUCTS

19. What are the means for transportation of various crops harvested?

Crop	Means of transport(***Do not read answers, circle all that apply***): 1) Pushcarts 2) Bicycle 3) Motor cycle 4) Tricycle 5) Donkey/oxen drawn carts 6) Truck/ pick up 7) Tractors with trailer 8) On head 9) Others (specify)…………	Ownership of the means of transport (***Do not read answers, circle all that apply***): 1) Own 2) Hired 3) Others…………
1. Maize	1 2 3 4 5 6 7 8 9	1 2 3
2. Rice	1 2 3 4 5 6 7 8 9	1 2 3
3. Beans	1 2 3 4 5 6 7 8 9	1 2 3
4. Sesame	1 2 3 4 5 6 7 8 9	1 2 3
5. Cowpeas	1 2 3 4 5 6 7 8 9	1 2 3
6. Sunflowers	1 2 3 4 5 6 7 8 9	1 2 3
7. Bananas	1 2 3 4 5 6 7 8 9	1 2 3
8. Cocoa	1 2 3 4 5 6 7 8 9	1 2 3
9. Cardamom	1 2 3 4 5 6 7 8 9	1 2 3
10. Tomatoes	1 2 3 4 5 6 7 8 9	1 2 3
11. Cassava	1 2 3 4 5 6 7 8 9	1 2 3
12. Mangoes	1 2 3 4 5 6 7 8 9	1 2 3
13. Oranges	1 2 3 4 5 6 7 8 9	1 2 3
14. Avocado	1 2 3 4 5 6 7 8 9	1 2 3
15. Teak	1 2 3 4 5 6 7 8 9	1 2 3
16. *Grevillea robusta*	1 2 3 4 5 6 7 8 9	1 2 3
17. Cocoa	1 2 3 4 5 6 7 8 9	1 2 3

20. To whom do you sell the various crops harvested [***Do not read answers; circle all that apply***]?

1. Direct to consumers
2. Rural brokers
3. Urban brokers
4. Wholesalers
5. Retailers
6. Others specify……………………………

SECTION 6: MARKET BARRIERS

21. Overall, what are the major challenges you face during marketing of your crops [***Do not read answers; circle all that apply***]?

    1) Poor roads_______
    2) Difficult terrain _______
    3) Distance to the market_______
    4) Storage of agricultural produces_______
    5) Accesses to pricing information_______
    6) Lack of adequate buyers_______
    7) Lack of unity among farmers_______
    8) Others (specify) ……………………………

22. How do you cope with marketing challenges identified in questions 23 [***Do not read answers; circle all that apply***]?

    1) Joining farmers union
    2) Making use of cereal banks
    3) Exploring prices in different markets
    4) Other (specify) ………………………………..

SECTION 5: AGRICULTURAL PRODUCT PRICE INFORMATION SYSTEMS

23. What are the means of accessing crop price information [***Do not read answers; circle all that apply***]??

    1) Contacting friends/neighbors
    2) Decided by buyers
    3) From radio/magazine
    4) You decide yourself
    5) Mobile phones
    6) Others (specify) ……………

24. How is the price of your crops decided [***Do not read answers; circle all that apply***]?

1) Production in that particular year
2) Other farmers selling at comparably lower prices
3) Buyers coming with their prices
4) You decide yourself
5) Others (specify) ……………..

25. Overall, what are means of adding values to your crops [***Do not read answers; circle all that apply***]?

1) Grading according to their quality
2) Packing
3) Transport them to market place
4) Semi processing
5) Final processing
6) Storage and sale when the price is high
7) Promotion of added services
8) Others (specify) ………………………

26. How do you store common cereal crops [***Do not read answers; circle all that apply***]?

1) Aerial storage
2) Smoking
3) Storage on the ground, or dry floors
4) Open timber platforms
5) Jars
6) Underground storage
7) Others (specify) ………………………

SECTION 6: ATTITUDES TOWARDS CONSERVATION

Cut-off scores: "0" Negative attitude, "1 – 2" Weak positive attitude, "3 – 4" Moderately positive attitude, "5 – 9" Highly positive attitude

27. What are the safe places for disposing unused pesticides? ***(Do not read answers, circle codes for all responses that apply)***

Code	Responses	Scores
[1]	Destroying in special incinerators	1
[2]	In rivers	0
[3]	In bush or thrown in farms nearby homesteads	0
[4]	Burying in farms around the homestead	0
[95]	Other ___________________	0
[-9]	Don't know	0

28. What type of fertilizer is safe to use in areas associated with sources of major rivers such South Nguru Mountains? ***(Do not read answers, circle codes for all responses that apply)***

Code	Responses	Scores
[1]	Organic fertilizer/cow manure/compost manure	1
[2]	Inorganic fertilizers	0
[95]	Other ___________________	0
[-9]	Don't know	0

29. What is the most appropriate and cheap method of land preparation especially when you have a large farm to prepare? ***(Do not read answers, circle codes for all responses that apply)***

Code	Responses	Scores
[1]	Hand hoe	1
[2]	Fire	0
[3]	Herbicides	0
[95]	Other (specify) ___________________	0
[-9]	I don't know	0

30. Is it true or false that tree cutting in South Nguru Mountains is the cause of climate variability? ***(Do not read answers, circle codes for all responses that apply)***

Code	Responses	Scores
[1]	True	1
[2]	False	0
[95]	Other ___________________	0
[-9]	Don't know	0

31. Do you see any benefits of prohibiting further expansion of farms into the forests in South Nguru Mountains? ***(Do not read answers, circle codes for all responses that apply)***

Code	Responses	Scores
[1]	Yes	1
[2]	No	0
[95]	Other ___________________	0
[-9]	Don't know	0

32. Do you think tree planting is of paramount importance to your life? ***(Do not read answers, circle codes for all responses that apply)***

Code	Responses	Scores
[1]	Yes	1
[2]	No	0
[95]	Other ___________________	0
[-9]	Don't know	0

33. Please explain whether the following statements are true or false in relation to life in South Nguru Mountains[Use a tick (✓)]

S/N	Statements	Circle appropriate response	
		TRUE	**FALSE**
1	Setting wildfires is an appropriate test for one's life expectancy	0	1
2	Use of fire for hunting is a safe practice as opposed to tree cutting	0	1
3	Setting wildfires is safe provided it is done during the evening	0	1

SECTION 7: FARMING PRACTICES

34. Do you see your land____ increasing,_____ decreasing or ____ no change in soil fertility? If increasing or decreasing explain why?____

35. Do you experience soil erosion on your land?

Yes _______

No_________

Don't know_______

36. Do you use any of the following farming practices? [***Read answers and tick (✓) the appropriate response***]

Farming practices	Response [Tick (✓)]		List tree/shrub species planted or used for intercropping	If you are not using, explain why
	YES	**NO**		
Terraces				
Tree planting				
Planting hedge rows				
Contour farming				
Intercropping trees with crops				
Natural fallowing				
Improved fallow				
Crop rotation				
Organic farming/agriculture				
Others (specify)				

THANKS FOR YOUR COOPERATION

Annex 5: Land suitability levels for selected crops in each land mapping unit within South Nguru Mountains Landscape in Mvomero district, Tanzania

Mapping unit	Crop type/lLand suitability															
	Maize	Rice	Beans	Cowpea	Banana	Mango	Citrus	Avocado	Cocoa	Teak	Cassava	Tomato	Sesame	Sunflower	*Grevillea robusta*	Cardamom
Broad valley in wet area	S2	S3	S3	S3	S3	S2	S3	S3	S3	S3	S3	N	S2	S3	S3	S3
Broad valley in dry area	S2	S2	N	N	N	S3	N	S2	N	S2	N	N	N	S2	S1	N
Flat to Undulating	S2	S2	S2	S3	S3	S3	N	S2	S2	S2	S2	S2	S2	S2	S2	S2
Flood plain	S2	S2	S3	S3	S3	S2	S3	S2	S2	S2	S3	S3	S3	S2	S2	S3
Foot ridges/hills in wet area	S3	N	S3	S3	S3	S2	S3	S3	S3	S3	S3	N	S3	S3	S3	S3
Steep slope mountain in dry area	N	N	N	N	N	S3	N	N	N	N	N	N	N	N	N	N
Moderate slope mountain in dry area	S3	N	S3	S3	S3	S2	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3
Moderate slope mountain in wet area	S3	N	S3	S3	S3	S2	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3
Steep slope mountain in wet area	N	N	N	N	N	S3	N	N	N	N	N	N	N	N	N	N
Foot ridges/hills in dry area	S3	N	S3	S3	S3	S2	N	S3	S3	S3	S3	S3	S3	S3	S3	S3

Key:

S1 = Highly suitable

S2 = Suitable

S3 = Marginally suitable

N = Not suitable

Annex 6: Community defined wealth indicators, criteria and categories in Digoma, Bwage, Mndela and Kinda villages in Mvomero district Tanzania

Wealth indicators	**Community-defined Wealth categories and indicators**			
	Non-poor	**Less poor**	**poor**	**poorest**
	1) Digoma village			
House owned Roof Wall floor Windows Doors Electricity	- Corrugated iron sheet - Burnt mud-bricks and cement made wall - Smooth floor made by cement -Made of steel and finished with wire mesh -Top made of finished wood and steel made gate - Generated from solar	- Corrugated iron sheet - Burnt mud-bricks and cement made wall -Smooth floor made by cement - Made of steel and finished with wire mesh -Top made of finished wood with no steel gate -N/A	-Roof made of palm leaves - Burnt mud-bricks wall - Smooth but dusty floor -Window built with bricks -Rough top or made of iron sheet -N/A	-Thatched with palm leaves or grasses -Wall made of mud -Rough dusty floor Door made of weaved palm leaves
Number and type of livestock owned Cattle Goats	Can own -1 to 3 -8 or above	Can own -0 to 1 -1 to 7	Can own -N/A - 0 to 2	Can own only -N/A -N/A
Pig Chicken Duck	-1 or above - 10 or above 10 or above	-1 or above -5 to 10 -5 to 10	-N/A -1 to 5 -1 to 5	-N/A -o to 3 -0 to 3
Food security (number of meals a day)	-Have adequate and can afford three meals a day, and can choose what to eat	Three meals a day and may not choose what to eat, eat whatever kind of food available	Two meal a day and have no choice of what to eat	Hardly one meal a day and completely have no choice of what to eat
Farm yield (Harvest)	-Harvest is normally high produce	Harvest is normally average	Harvest is usually low	Very low or no harvest
Size of farm/land owned	Can own -3 to 5 acres	Can own -1 to 3 acres	Can own -0.5 to 1.5 acres	Can own -0.5 to 1 acres
Farm implement and machinery Tractor Casual labor	Can use -Hire tractor -Casual labor or -Combination of two	Can use -Casual labor -Self (hand hoes) -Sometime combination of two	-Do themselves with hand hoes	-Use hand hoe themselve

Wealth indicators	Community-defined Wealth categories and indicators			
	Non-poor	**Less poor**	**poor**	**poorest**
Ability to access health services	-Can afford health care (Treatments) from private hospital found around the area and Morogoro -And also hospitals found in Dar es salaam	- Can afford health care (Treatments) from private hospital found around the area and Morogoro municipality	-Acquire health services from public (Government) health centers available in the village	Can acquire health services from public (Government) health centers in the village but with difficult
Ability to send children to school	Can support/send children --for primary education and secondary education in private school available in the district and Morogoro municipality	Can support/send children --for primary education and secondary education in private school available in the district and Morogoro municipality	-Send children to public primary schools -Also can support children but with difficult to secondary education in public schools in the area	-Send children to public schools and only primary level but with difficulties and sometime do not send children to school
Type and number of transport facilities owned Motorcycle Bicycle	Can own -1 Motorcycle or above -1 bicycle or above	Can own -0 or 1 Motorcycle -1 bicycle or above	Can own -0 or 1 bicycle	N/A
Income generating activity undertaken (Off-farm activities) Retail shop Agricultural crop Bar Hire Motorcycle	Can operate -Retail shop -Buy and sell agricultural produce -Selling beer and soft drinks -Hire motorcycle (Boda boda)	Can operate - Retail shop -Buy and sell agricultural produce but not much as non-poor -Some operate boda boda	Can operate -Sell vegetables -Sell agricultural produces -Do casual labor -Mansion -Make and sell local brew Motorcycle drivers (Boda boda)	-Do casual labor -Sell their land when serious problem arises
	2) Bwage village			
House owned Roof Wall floor Windows Door Electricity	Corrugated iron sheet Burnt mud-bricks and cement made wall Smooth floor made by cement and or tiles Made of finished lumber with wire mesh Top made of	-Corrugated iron sheet Burnt mud-bricks and cement made wall Smooth floor made by cement -Made of finished lumber -Top made of finished wood	-Corrugated iron sheet or thatched with grasses Burnt bricks or mud wall Dusty floor Covered with brick	Thatched with grasses Wall made of poles and mud

Wealth indicators	Community-defined Wealth categories and indicators			
	Non-poor	**Less poor**	**poor**	**poorest**
	finished wood -Use own solar			
Number and type of livestock owned Cattle Goats Pig Chicken	Can own -1 to 10 and above -10 or above - 2 or above - 15 to 30	Can own -1 to 5 - 5 to 10 - 0 to 2 -10 to 20	Can own -N/A - 0 to 5 -0 to 1 - 5 to 15	Can own only -N/A -0 to 4 -N/A - 0 to 5 Chicken
Size of farm/land owned	Can own -5 to 30 acres	Can own -5 to 10 acres	Can own -1 to 5 acres	Can own -1 to 2 acres
Farm implement and machinery Tractor Casual labor	Can use -Tractor -Casual labor or -Combination of two	Can use -Hire tractor -And casual labor - Combination of two	Hand hoe	Hand hoe
Type and number of transport facilities owned Vehicle Motorcycle Bicycle	Can own -0 to 1 car -1 Motorcycle or above -1 bicycle or above	Can own -N/A -0 or 1 Motorcycle -1 bicycle or above	Can own -0 or 1 bicycle	N/A
Farm yield (Harvest)	-Harvest is normally high produce	Harvest is normally average	Harvest is usually low	Very low or no harvest
Food security (number of meals a day)	Have adequate and can afford three meals a day, and can choose what to eat	Three meals a day and may choose what to eat, eat sometime cannot choose	Two meal a day and have no choice of what to eat	One meal or two a day but with difficult and completely have no choice of what to eat
Ability to access health services	Can afford health care (Treatments) from private hospital found around the area and outside Morogoro region	Can afford health care (Treatments) from private hospital found around the area and outside Morogoro region	Acquire health services from public health centers available in the village and district	Acquire health services from public health centers available in the village
Ability to send children to school	Can support/send children for primary education and secondary education in private school available in	Can support/send children for primary education and secondary education in private school available in	Send children to public primary schools Also can support children to secondary	Send children to public schools and only primary level but with difficulties _And sometime do not send children to

Wealth indicators	Community-defined Wealth categories and indicators			
	Non-poor	**Less poor**	**poor**	**poorest**
	and outside Morogoro region	and outside Morogoro region	education in public schools but with difficulties and sometimes do not.	school
Income generating activity undertaken (Offfarm activities)	Can operate Retail shop Storerooms and houses for rent Buy and sell agricultural produce Milling machine Transportation Machine generating electricity	Can operate Retail shop Buy and sell agricultural produce but not much as nonpoor Milling machine House for rent	Can do casual labor Sell agricultural produce occasionally	Casual labor
	3) Mndela village			
House owned Roof Wall floor Windows Doors Electricity	Corrugated iron sheet Burnt mudbricks and cement made wall Smooth floor made by cement Made of finished lumber Top made of finished wood N/A	Corrugated iron sheet Burnt mud-bricks and cement made wall Smooth but dusty floor Made finished wood Top made of finished wood N/A	Corrugated iron sheet or thatched with grasses Mud wall Smooth but dusty floor Window built with bricks Rough top or made of iron sheet N/A	Thatched with grasses Wall made of mud Rough dusty floor Door made of iron sheet
Number and type of livestock owned Cattle Goats Pig Chicken Duck	Can own to 10 to 20 0 to 4 10 or above 10 or above	Can own 0 to 5 to 10 1 to 3 to 10 5 to 10	Can own N/A 0 to 2 N/A 1 to 5 1 to 5	Can own only N/A N/A N/A to 4 0 to 4
Food security (number of meals a day)	Have adequate and can afford three meals a day, and can choose what to eat	Three meals a day and may not choose what to eat, eat whatever kind of food available	Two meal a day and have no choice of what to eat	Hardly one meal a day and completely have no choice of what to eat
Farm yield (Harvest)	Harvest is normally high produce	Harvest is normally average	Harvest is usually low	Very low or no harvest
Size of farm/land owned	Can own 5 to 8 acres	Can own 1 to 4 acres	Can own 1 to 2 acres	Can own 0.5 to 1 acres

Wealth indicators	**Community-defined Wealth categories and indicators**			
	Non-poor	**Less poor**	**poor**	**poorest**
Farm implement and machinery Tractor Casual labor	Can use N/A Casual labor	Can use Casual labor Self (hand hoes)	Do themselves with hand hoes	Use hand hoe themselves
Ability to access health services	Can afford health care (Treatments) from private hospital found in the district	Can afford health care (Treatments) from public health centre in Mkindu	Acquire health services from public (Government) health centers available in Mkindu but with difficult	Can acquire health services from public (Government) health centers but with difficult and sometime not able
Ability to send children to school	Can support/send children for primary education and secondary education in private school available in the district	Can support/send children for primary education and secondary education in public school available in the district and	Send children to public primary schools only	Send children to public schools and only primary level but with difficulties and sometime do not send children to school
Type and number of transport facilities owned Motorcycle Bicycle	Can own to 1 Motorcycle N/A	N/A	N/A	N/A
Income generating activity undertaken (Off farm activities) Retail shop Agricultural crop Milling machine	Can operate Retail shop Buy and sell agricultural produce operate milling machine	Can operate Make and sell local brew Buy and sell agricultural produce but not much as nonpoor	Can operate Sell agricultural produces Do casual labor	Do casual labor
	4. Kinda Village			
House owned Roof Wall floor Windows Doors Electricity	Corrugated iron sheet Burnt mudbricks and cement made wall Smooth floor made by cement Made of finished lumber with glass Top made of finished wood and steel made gate Generated from solar	Corrugated iron sheet Burnt mudbricks and cement made wall Smooth floor made by cement Made of finished lumber Top made of finished wood Generated from solar	Corrugated iron sheet or thatched grasses Wall made of pole and withies Smooth but dusty floor Rough top or made of iron sheet N/A	Dilapidated houses thatched with grasses Wall made of mud Rough dusty floor Door made of iron sheet

Wealth indicators	Community-defined Wealth categories and indicators			
	Non-poor	**Less poor**	**poor**	**poorest**
Number and type of livestock owned Cattle Goats Pig Chicken	Can own to 20 10 or above 1 or above 10 or above	Can own 2 to 5 to 10 1 or above 5 to 10	Can own N/A 0 to 4 0 to 1 2 to 5	Can own only N/A 0 to 2 N/A 0 to 2
Food security (number of meals a day)	Have adequate and can afford three meals a day, and can choose what to eat	Three meals a day and may not choose what to eat, eat whatever kind of food available	Two meal a day and have no choice of what to eat	Hardly one meal a day and completely have no choice of what to eat
Farm yield (Harvest)	Harvest is normally high produce	Harvest is normally average	Harvest is usually low	Very low or no harvest
Size of farm/land owned	Can own 2 to 10 acres	Can own 2 to 4 acres	Can own 1 to 2 acres	Can own 0.5 to 1 acres
Farm implement and machinery Tractor Casual labor	Can use N/A Casual labor or And themselves	Can use N/A Casual labor Self (hand hoes)	Do themselves with hand hoes	Use hand hoe themselves
Ability to access health services	Can afford health care (Treatments) from private hospital found around the area and Morogoro And also in Muhimbili national hospital in Dar es salaam	Can afford health care (Treatments) from private hospital found around the area and Morogoro municipality	Acquire health services from public (Government) health centers available in the village	Can acquire health services from public (Government) health centers in the village but with difficult

Wealth indicators	Community-defined Wealth categories and indicators			
	Non-poor	**Less poor**	**poor**	**poorest**
Ability to send children to school	Can support/send children for primary education and secondary education in private school available in the district and Morogoro municipality Also outside the region	Can support/send children for primary education and secondary education in private school available in the district and Morogoro municipality	Send children to public primary schools Also can support children but with difficult to secondary education in public schools in the area	Send children to public schools and only primary level but with difficulties and sometime do not send children to school
Type and number of transport facilities owned Motorcycle Bicycle	Can own 1 Motorcycle or above 1 bicycle or above	Can own 0 or 1 Motorcycle 1 bicycle or above	Can own 0 or 1 bicycle	N/A
Income generating activity undertaken (Off-farm activities) Retail shop Agricultural crop Milling machine Hire Motorcycle	Can operate Retail shop Buy and sell agricultural produce Milling machine Hire motorcycle (Boda boda)	Can operate Retail shop Buy and sell agricultural produce but not much as nonpoor Some operate boda boda Food vending	Can operate Sell agricultural produces after harvesting Do casual labor Make and sell local brew Motorcycle drivers (Boda boda)	Do casual labor

Annex 7: Causal analysis of the key agriculture problem around Nguru South Mountains Landscape as analysed during focus group discussions with community representatives

Narrative summary	Villages			
	Digoma	Bwage	Mndela	Kinda
Effects of the problem	Absenteeism and pupils dropout Parents fail to meet school financial requirements for their children Decrease in household income Hunger	Hardship in living Low household income Hunger	Hardship in living Low household income Hunger	Hardship in living Low household income Hunger
Principle problem	Decline in crop yields	Decline in crop yields	Decline in crop yields	Decline in crop yields
Immediate causes	Unreliable rainfall and frequent drought Decline in soil fertility	Climate variability and frequent droughts Deterioration of soil fertility	Climate variability and frequent droughts Decreased soil fertility Disease affecting crops	People do not follow farming principles and techniques Drought Disease affecting crops
Intermediate causes	Continuous cropping without any external inputs Increase in population Many people migrate in the area in search for fertile land	Continuous cropping without any external inputs People dismayed due to high cost of farm inputs	Increase in population Soil erosion Lack technical know-how on soil conservation measures Continuous cropping without any external inputs	Drought Soil erosion
Underlying causes	Inadequate household incomes to purchase agricultural inputs (*pembejeo*) Inadequate technical capacities among extension workers on supporting community development Remoteness of the villages discourage the extension workers to stay in the village Inadequate support and monitoring for the extension	Inadequate household incomes to purchase agricultural inputs (*pembejeo*) Inadequate agricultural extension workers Inadequate support and supervision for extension workers at ward and district levels	Inadequate household incomes to purchase agricultural inputs (*pembejeo*) Farming practices that do not follow farming principle and techniques Illiteracy Inadequacy of agricultural experts due to unemployment Lack of capital Lack of subsides (Pembejeo)	Inadequate household incomes to purchase agricultural inputs (*pembejeo*) Low level of understanding in the community Customs Lack of accountability and creativity Unreliable market for farm produce Lack of market information Lack of unity among farmers Lack of motivation

Narrative summary	Villages			
	Digoma	Bwage	Mndela	Kinda
	workers at the ward, district and regional levels Inadequate capacity of village leaders to control in migration			from leaders Lack of capital Lack of subsides (Pembejeo)

Annex 8: Causal analysis of the key forest resource management problem around South Nguru Mountains Landscape as analysed during focus group discussions with community representatives

Narrative summary	Villages			
	Digoma	Bwage	Mndela	Kinda
Effects of the problem	Shortage of firewood Frequent droughtsl Decreased water flow and inadequate water for irrigation	Frequent droughts Shortage of firewood and building poles Decreased water flow/drying rivers	Decline in water flow in rivers Shortage of firewood and building poles Decreased water flow and drying of some rivers	Shortage of firewood Wildfire: The presence of arsonists, hunters, and land preparation using fire
Principle problem	Disappearance of forest	Disappearance of forest	Disappearance of forest	Disappearance of forest
Immediate causes	Clearing forests for agricultural expansion Illegal tree harvesting for timber and charcoal making	Clearing forests for agricultural expansion Wildfire Illegal tree harvesting for timber and charcoal making Overgrazing in the forest	Clearing forests for agricultural expansion Clearing forests for mining Tree cutting for timber and charcoal making Grazing in the forest Wildfires	Clearing forests for agricultural expansion Tree cutting for timber and charcoal making to earn incomes Forest degradation by wildfires Over grazing
Intermediate causes	Decline in farm fertility in the ordinary farms Decline in farm holding due to siltation in the valley bottom farms Population increase as many people migrating in the area to search for farming land Natural population increases due to birth and rebirth	Decline in soil fertility in farms Low household income Inadequate opportunities for income generating sources Influx of pastoralists from other places Inadequate extension services to promote better soil forest management practices	Decline in soil fertility in ordinary farms Inadequate opportunities for income generating sources Inadequate opportunities for income generating activities Inadequate awareness on the dangers of wildfires Inadequate knowledge on improved farming practices	Decline soil fertility Inadequate opportunities for income generating sources Increased human and livestock population Inadequate awareness on the dangers of wildfires Inadequate opportunities for income generating activities
Underlying causes	Inadequate capacity for the village government to control in-migration Inadequate agricultural extension services Inadequate capacity for the community members to hold accountable their duty bearers Remoteness of the village repels the extension workers Inadequate support for village development from	Inadequate development support for ward, district, regional and national levels Inadequate extension workers on livestock production Corruption among those charged with enforcing the forest law Poverty	Inadequate agricultural extension services Inadequate capacity to enforce forest law at all levels Poverty	Increased human population Poverty No other income generating activities Inadequate knowledge on improved farming practices Continuous cropping without any external inputs

	ward, district, regional and national level Shortage of extension workers for water resource management Bad decision made by early village leaders and government officials in 1980s to channel river Mjonga into river Msanya has caused frequent flooding of the valley bottom farms			

Annex 9: Causal analysis of the key water resource management problem around South Nguru Mountains Landscape as analysed during focus group discussions with community representatives

Narrative summary	Villages			
	Digoma	Bwage	Mndela	Kinda
Effects of the problem	Flooding due to bad decision by early village leaders to join two rivers (Mjonga and Mnyasa) Food insecurity in the village (Hunger) Availability of water is a problem in the village Destruction of farms in lowland areas Decrease in production	Reduced production from other productive activities Shortage of water Decrease in lowland farming practice Lowland farming practices affected other activities negatively	Waterborne diseases Shortage of water Reduced production in lowland areas Reduced production in irrigation agriculture scheme Fetching water far from the village	Waterborne diseases Shortage of water Reduced production in lowland areas Reduced production in irrigation agriculture scheme Fetching water far from the village
Principle problem	Flooding and Contaminated water	Drying of water sources	Drying of water sources Contaminated water	Drying of water sources Contaminated water
Immediate causes	Clearing forest land and farming on water sources Shifting cultivation or following fertile land in the forest area	Drought Farming near river banks Rigorous tree cutting	Farming near river banks and water sources Tree cutting for timber and charcoal Drought Mining	Cutting trees near water sources (riparian zones) Mining activities in water sources Drought
Intermediate causes	Deterioration of many farm in lowland area Insufficient farm land in the village Increased human population	Low income to majority Increase in human population	Low farm harvest and income of the household Increase in human population	Farmland preparation Increase in human population
Underlying causes	Failure of village government to control migrants Poor understanding of land use planning Experts do not like to live/stay in remote areas particular villages Lack of experts on water management Village leader and community in	Lack of education on forest management Inadequate experts in forest and water resources In ability of village government to enforce laws Poor management from ward to national level	Laws are not followed Corruption Lack of alternative income generating activities (forced to mining activities)	People do not abide the laws Poor law enforcement Corruption Lack of alternative income generating activities (forced to mining activities)

Narrative summary	Villages			
	Digoma	Bwage	Mndela	Kinda
	general have poor understanding on water resource management Inadequate forest experts In ability of village government to implement forest conservation laws Bad decision made by early villages leaders to join river Mnyasa and Mgonja			

Annex 10: Summary of net present values for different crops/crop combinations for different cropping systems in South Nguru Mountains Landscape in Mvomero district, Tanzania

Crops/crop combination	**Cropping system**	**Agro-ecological zone**	**Years**				
			1	**5**	**10**	**20**	**25**
			NPV x 1000 TAS	**NPV x 1000 TAS**	**NPV x 1000 TAS**	**NPV x 1000 TAS**	**NPV x 1000 TAS**
Rice	Continuous cropping	Dry lowland	221	1,374			
		Humid lowland	647	2,345			
	Fertilizer app.	Dry lowland	321	4,504			
		Humid lowland	694	7,510			
Bean	Continuous cropping	Dry lowland	695	2,190			
		Humid lowland	99	913			
		Leeward highlands	179	711			
		Windward highlands	201	952			
	Agroforestry	Dry lowland	316	6638			
		Humid lowland	-391	3,043			
		Leeward highlands	-415	3,142			
		Windward highlands	-376	3870			
	Fertilizer app.	Dry lowland	969	8,472			
		Humid lowland	-22	3,609			
		Leeward highlands	80	3,781			
		Windward highlands	164	4,708			
Maize	Continuous cropping	Dry lowland	234	1,025			
		Humid lowland	634	1825			
		Leeward highlands	4	338			
		Windward highlands	0.6	360			
	Agroforestry	Dry lowland	-142	5666			
		Humid lowland	426	10165			
		Leeward highlands	-601	2466			
		Windward highlands	-600	2558			
	Fertilizer app.	Dry lowland	1400	9686			
		Humid lowland	3285	18273			
		Leeward highlands	146	3670			
		Windward highlands	166	3825			

Crops/crop combination	Cropping system	Agro-ecological zone	Years				
			1	5	10	20	25
			NPV x 1000 TAS	NPV x 1000 TAS	NPV x 1000 TAS	NPV x 1000 TAS	NPV x 1000 TAS
Sesame	Continuous cropping	Dry lowland	381	1,363			
		Humid lowland	431	1,645			
	Fertilizer app.	Dry lowland	596	6,251			
		Humid lowland	732	7,300			
Sunflower	Continuous cropping	Dry lowland	137	860			
		Humid lowland	140	1,066			
	Fertilizer app.	Dry lowland	147	4,112			
		Humid lowland	216	4,845			
Peas	Continuous cropping	Leeward highlands	109	588			
		Windward highlands	84	547			
	Fertilizer app.	Leeward highlands	-69	3,016			
		Windward highlands	-107	2,817			
Tomatoes	Continuous cropping	Humid lowland	755	2,317			
		Leeward highlands	697	4,946			
		Windward highlands	1,425	3,449			
	Fertilizer app.	Humid lowland	435	6,126			
		Leeward highlands	307	14,550			
		Windward highlands	1,035	11,626			
Rotation: Maize-Sunflower	Agroforestry	Dry lowland	14	2,997			
	Fertilizer app.		1514	6,693			
	Agroforestry	Humid lowland	545	4,881			
	Fertilizer app.		3,319	12,023			
Rotation: Maize-sesame	Agroforestry	Dry lowland	-5	3371			
	Fertilizer app.		1494	7445			
	Agroforestry	Humid lowland	523	5303			
	Fertilizer app.		3297	12,888			
Rotation: Maize-cocoyam	Agroforestry	Humid lowland	426	10165	10165		
		Leeward highlands	-601	2466	2466		
		Windward highlands	600	2558	2558		
Beans-cocoyam	Agroforestry	Humid lowland	-447	3342	3342		
		Leeward highlands	-478	3476	3476		
		Windward highlands	-456	4299	4299		

Crops/crop combination	Cropping system	Agro-ecological zone	Years				
			1	5	10	20	25
			NPV x 1000 TAS	NPV x 1000 TAS	NPV x 1000 TAS	NPV x 1000 TAS	NPV x 1000 TAS
Banana-Maize	Intercropping	Highlands	785	3,771			
Cassava-Maize	Intercropping	All zones	3,392	8,485			
Maize-peas intercropping	Continuous cropping	Humid lowland	160	187			
		Leeward highlands	187	1014			
		Windward highlands	194	1243			
	Fertilizer	Humid lowland	850	7508			
		Leeward highlands	444	5405			
		Windward highlands	492	6170			
Sugarcane-maize	Intercropping	All zones	1155	5644			
Cocoa-maize	Fruit tree-crop intercropping	Highlands	-219	1,463	4,919		
Avocado-maize	Fruit tree-crop intercropping	Highlands	-188	1166	6255		
Mangoes-Maize	Fruit tree-crop intercropping	Humid lowland	227	3,233	13433		
Oranges-Maize	Fruit tree-crop intercropping	Humid lowland	277	3,544	9134		
Teak-Maize	Timber tree-crop intercropping	Humid lowland	377	3,264	4,899	5,481	19,799
Grevillea-Maize	Timber tree-crop intercropping	Leeward highlands	-245	1010	1,332	6014	
		Humid lowland	377	3,933	4,762	9,471	