Declining Soil Fertility: A Challenge For Sustainable Productivity of Land under Cashew Farms, Southern Areas of Tanzania

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Abstract

Over the past two decades the production of cashewnut in the southern coast of Tanzania has declined due to infestation of trees by flowery powdery mildew disease (PMD). Originally, the control strategy was the application of elemental sulphur dust on cashew trees. This was realized to be environmentally unsustainable due to soil acidification by sulphur, leading to declining soil fertility. The use of organic fungicides, and proper application of residues have been advocated. This study examined various farming practices and their implications to livelihood of people, the current status of soil fertility, adoption rate of organic fungicides in cashew growing areas and investigated how farmers are responding to declining soil fertility through organic residue management. The study further explored other development problems facing the people through Participatory Rural Appraisal (PRA) and households surveys supplemented by field visits. Through laboratory incubations, the potentials of various organic residues in ameliorating soil acidity associated with sulphur dusting and effects on the growth of maize were also investigated. Findings from this study show that sulphur is still a major fungicide used in both zones and this poses a threat to soil fertility. The adoption of alternative organic fungicides is still slow due to various reasons, such as poor institutional framework and dissemination. The application of organic residues on soils seems to be the best option for managing soil fertility and this needs to be promoted. There is an urgent need to review the agricultural land ownership systems since currently elders tend to own large proportions of land under cashew which encourages out migration of youth into urban areas to look for non farm activities. This leads to poor management of soil resources because elders cannot manage properly large farms.

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Introduction

Soils found in the southern coastal areas of Tanzania particularly in the cashew growing areas, which include Mtwara and Lindi regions are acidic in reaction and may contain toxic levels of Aluminium and other metal cations which are often the major constraints to crop production (Majule *et al.*, 1997). They are also characteristically sandy in nature with very low soil organic matter contents with the exception of soils located on the valley bottoms (Bennett *et al.*, 1979; Baker, 1995; Majule *et al.*, 1997).

Cashewnut (*Anarcardium occidentale*, L.) is one of the major perennial cash crops in Tanzania. Cashewnut was ranked as one of the most important foreign exchange earning crops at national level in the year 2000 being exceeded only by coffee (URT, 1999; Bank of Tanzania, 2000). Tanzania's production is about 9% of the world total (FAO, 2000).

The crop is grown mostly by smallholder farmers estimated to number some 280 000, on approximately 400 000ha of mono - or mixed - crop production systems. One major problem that affects the production of cashewnut is the infestation of trees by powdery mildew disease (PMD) which can reduce yields to zero under severe epidemics (Casulli, 1981; Smith *et al.*, 1995). The common adopted control strategy is application of sulphur dust on cashew trees (Intini and Sijaona, 1983; Sijaona, 1984). This control strategy has been associated with the soil acidification due to the oxidation of sulphur (Majule *et al.*, 1997; Ngatunga *et al.*, 1997). Other organic fungicides including triadimenol (Bayfidan, EC 250 g ai/l), haxaconazole (Anvil, EC 50g ai/l) and penconazole (Topas, EC 100g ai/l) have been recommended in place of sulphur. The rate of their adoption and their implication on environment is however not clearly known.

The productivity of tree crops on inherently poor soils depends on the process of nutrient cycling that occurs through leaf-fall and the gradual decomposition of surface organic matter. Increased leaching caused by greater acidity enhanced by sulphur oxidation has been found to disrupt this process because exchangeable cations (Ca^{2+}, Mg^{2+} and K^{+}) are leached from the top soil (Majule *et al.*, 1997). Theoretically, the interrelationships among different factors influencing soil fertility and it implications on poverty levels can be presented schematically as shown in Figure 1.

The number of farmers who are able to use artificial fertilizers to replace nutrients removed through crop harvest is very low due to lack of capital to purchase fertilizers and lack of education with regard to the importance of fertilizers. Generally, organic residues seem to be the only source of plant nutrients in cashew farming system since none of the farmers use fertilizers in cashew farms. Of particular concern is the potential effect of soil acidification associated with sulphur dusting on the production of intercrops and the overall sustainability of poor soils found in cashew farming system in the southern zone (Majule et al., 1997; Ngatunga *et al.*, 1997; Majule, 2001; Majule and Nortcliff, 2001). Major limiting plant nutrients in cashew farming system include nitrogen, phosphorus, and potassium (Baker, 1995).

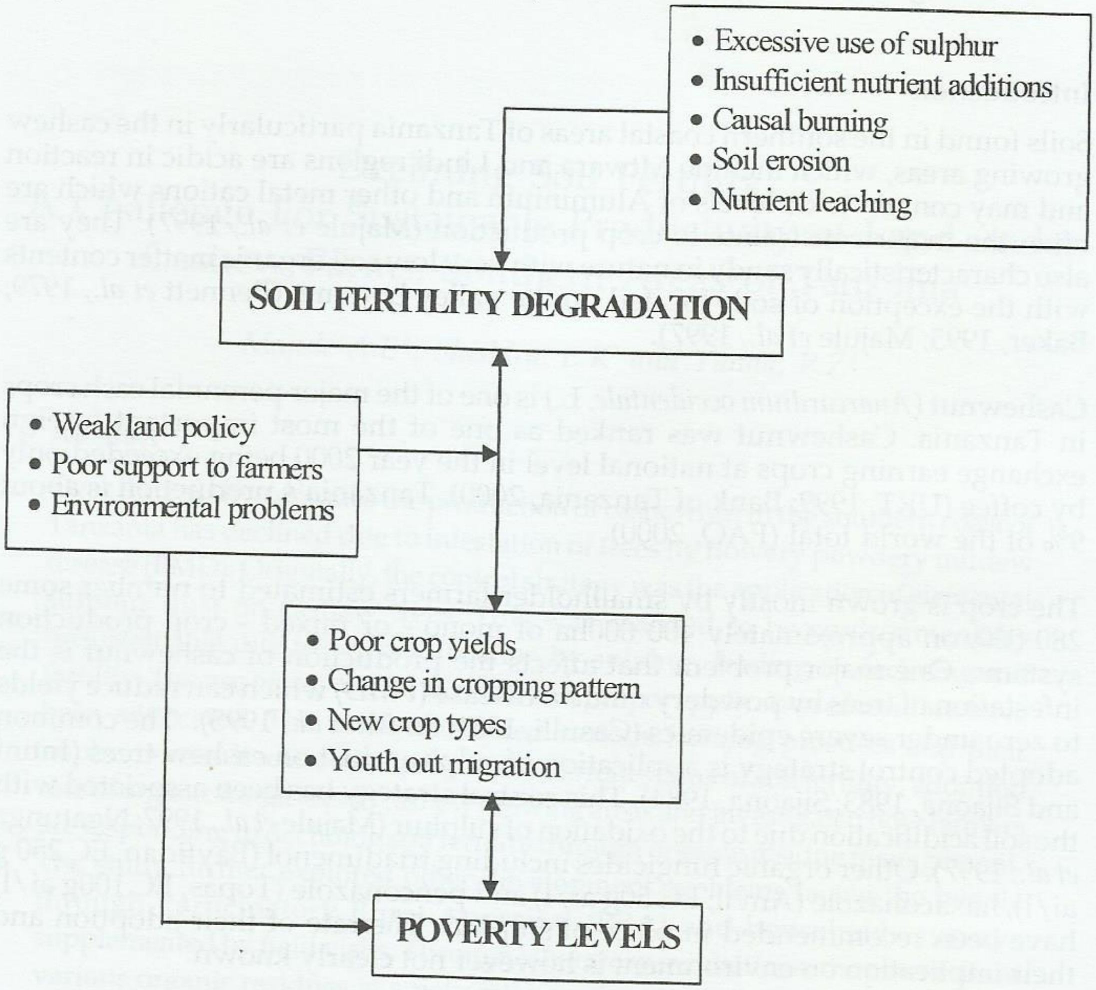

Figure 1: A Theoretical Framework of Different Factors Influencing Soil Fertility and Poverty Levels

Farmers in the study area have reported rapidly declining soil fertility a short time after fallow land is put into arable farming as one of the major factors which results in low crop productivity. Studies conducted in the same area (Likanda *et al.*, 1995) have shown that farmers are aware of the problem and have been involved in different local or indigenous soil fertility management practices to address the problem. The constant addition of organic residue to soils for example, is reported to have sustained crop production for a period of five years without opening new land (Majule, 1999). On the other hand, incubation experiments involving soils, different levels of sulphur with or without cashew, maize or goat FYM have indicated that soil acidity can be reduced in various magnitudes by the different sources (Majule, 1999). However, there is a limited body of knowledge with regards to the effectiveness of different organic residues added to soils under cashew in order to improve soil fertility and ameliorate soil acidity generated by sulphur.

A survey on soil fertility management, characterization of residues and investigation of their effectiveness is therefore imperative. The aim of this study was therefore to examine the current status of declining soil fertility, adoption rate of organic fungicides in cashew growing areas and to investigate on how farmers are responding to declining soil fertility. The study also investigated the effects of organic residues and sulphur applications on soil pH and crop growth. Other development constraints were also investigated.

Research Methodology

Site selection and field Survey

The southern area of Tanzania is famous in the production of cashewnut, a cash crop which is beneficial to both small-scale growers and the nation in terms of generating foreign income. There are two major agro-ecological zones in the southern coastal areas, which are potential for the production of cashewnut namely AEZ C2 and AEZ E5 as described by De Pauw (1984). In each of the zones, two villages namely Makukwe and Naipanga in Newala (AEZ C2) and Nachingwea (AEZ E5) were selected after consulting the District and Agricultural and Livestock Development Officers (DALDO's) in the two Districts. Major criteria used in the selection of villages were;

- A village with a minimum of 400 households, a representative feature for many villages.
- A village that depends mainly on the production of cashew, ample land for further research.
- A village near the main road for easy accessibility to market centers
- A village that previously showed co-operation in research or other development activities.

The number of households at Makukwe and Naipanga villages are 795 and 800 respectively providing a wide range of socio-economic activities which allow comparison across sites. Socio-economic data were collected through Participatory Rural Assesment and then followed by household surveys, which were conducted using a semi-structured questionnaire. The interview targeted those people who own cashew fields. Key information assessed are those related to household characteristics, agricultural practices, soil resource management and land tenure systems. In this case for example, farmers were asked to rank the status of their soils in terms of fertility and then to state the trend for the past ten years. The farmers were also asked to explain different soil fertility management practices, cropping patterns, rates of fungicides use and other related issues.

Assessment of the Effect of Organic Residues on Crop Growth and Soil pH

The approach used has been reported in details by Omollo (2002 pp 31-34). Sampling of soils and residues (Cowpea, *Cordia* spp. Pigeon peas and Wildspiknard) was undertaken after household survey. Both soils were assessed for fertility and organic residues for their chemical composition. For the purpose of reporting in this paper and to understand or confirm some of the theoretical findings reported, collected Arenosol soil was incubated with different fractions of sulphur together or without the four organic residues mentioned. The main aim was to examine the effect of treatments on soil pH and crop growth. This was done at the Sokoine University of Agriculture (SUA) in Morogoro as part of this study.

Study Area

Biophysical Characteristics

Agro - ecologically, Mtwara Region and Nachingwea District in Lindi Region are located in AEZ C2 and E5 respectively. Climatic conditions in Mtwara and Lindi regions are influenced by the southeast trade winds in mid year and the northeast tradewinds during the turn of the year. Temperatures vary little, the average mean temperature being 24.3°C in the coolest month of August and 27.5°C in December, the hottest month. The mean maximum temperature is 30.5°C and the mean minimum is 21.7°C.

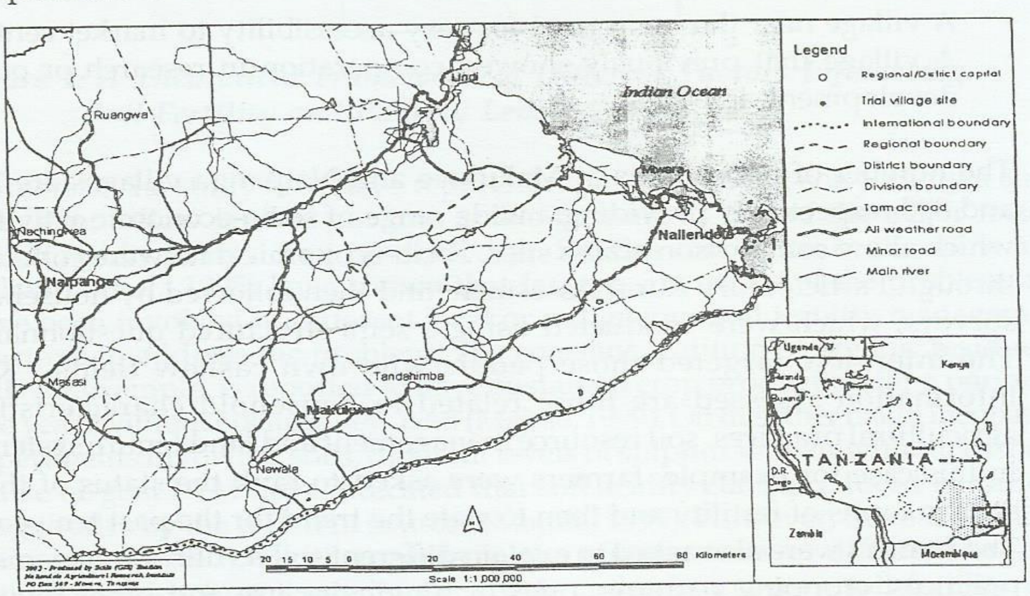

Figure 2: Geographical Location of Makukwe and Naipanga in Newala and Nachingwea

The rainfall pattern in the southern zone is unimodal but often has a seasonal interruption. Approximately 85% of precipitation falls between December and April, which are defined as 'wet' months on the basis of a minimum of 50 mm precipitation. Average annual precipitation for both Regions varies between 810 mm and 1090 mm.

The soils are formed in terrestrial Karoo, Cretaceous and Neogene deposits which are invariably deep and lack surface stone. The soils are impoverished and the surface organic matter is the only nutritive resource. Two dominant soils found in selected sites for research are **Luvic Arenosol** and **Rhodic Ferralsol.** Soils are characteristically very low in available nutrients, poor water holding capacity and they are very sensitive to water erosion. Similar soils found near the study areas are described in details elsewhere (see for example Bennett *et al.*, 1979; Baker, 1995; Ikerra *et al.*, 1995; Majule, 1999).

Irrigation is possible in limited areas, particularly in flood plains. The majority of farmers therefore depend on rainfall water to produce food crops. Most of the maize consumed in both Regions is produced from AEZ 5 and much of cashewnut is produced in AEZ C2.

Results and Discussions

Economic activities and population structure

Makukwe village in Newala district is a representative site for AEZ C2 (Figure 2). The total number of households in the village is 795 (402 households originating from Makukwe and 393 from Nanjelele). Naipanga village, a representative for AEZ E5, is found in Nachingwea district and is located along the main road to Masasi district from Nachingwea. The total number of households in the village is around 800. The population structures of the two villages based on sex and age of the household's head is presented in Table 1.

Table 1: Sex Ratio (%) of Household heads in the two Villages

Village	Male	Female
Makukwe	82	18
Naipanga	73	27
Average	**78**	**22**

Source; Survey data 2001

In both villages, most of the household heads are male. However, during PRA and field observations it was found that despite more families being headed by male, females undertake most of agricultural activities at household level. These activities include land preparation, planting, harvesting and processing of both food and cash crops. It was also learnt that the final decision on how to use food or cash obtained from the sale of cash crops is normally made by a male. Figure 3 indicates the age distribution of populations in the two villages investigated, from which the following major conclusions can be drawn:

- The proportion of Households headed by a group of young people (18-28 years old) at Makukwe in Newala is very small compared to Nachingwea. This situation is very common in Newala district and the main reasons are two: The first one is out - migration of young people to towns particularly Dar es Salaam where they perform petty trade (Wamachinga). Second, lack of land to allocate young generation (see for example Figure 5).
- Similar explanations can be made for people in the age groups of between 28-38 as well as age groups between 28-48 years old since the reasons are extended to older people.
- At Makukwe in Newala district nearly 50% of households are headed by males within the age group of >58 years. This has the following implications; first, because of their age, they have lost much of the energy that is needed in the management of organic residues in soils, the work which needs much energy and labor. Second, there is little education on the importance of organic residues application in soils.

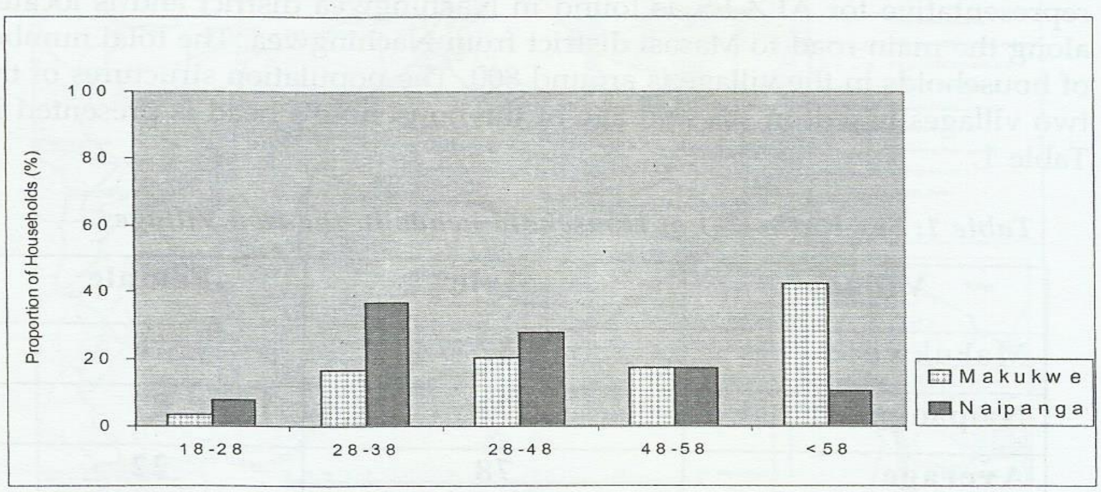

Figure 3: Age Distribution in Makukwe and Naipanga Villages

From these results, it should be recognized that there is a need to change the land ownership system in Newala district such that it benefits the young generation which is more adaptive, energetic and productive in order to have sustainable soil resource management.

The survey data also revealed that the major economic activity is agriculture whereby most people are engaged in the production of both food and cash crops. A very small proportion of people tend to keep livestock alone in Naipanga village. In both villages, the proportion of households engaged in various forms of agricultural activities is given in Figure 4. Very few people (<5%) keep livestock alone in Naipanga village and none of them in Makukwe village. Over 60% of HH in both villages are engaged in the production of different food and cash crops (Table 2). On the other hand, nearly 40% of households in both villages depend on both crops and livestock. Livestock keeping is so important not only as a source of protein but also for income generation. Manure from livestock together with crop residues form the major source of soil nutrient. Therefore, promotion and improvement of these farming practices can ensure soils productivity and improve food security.

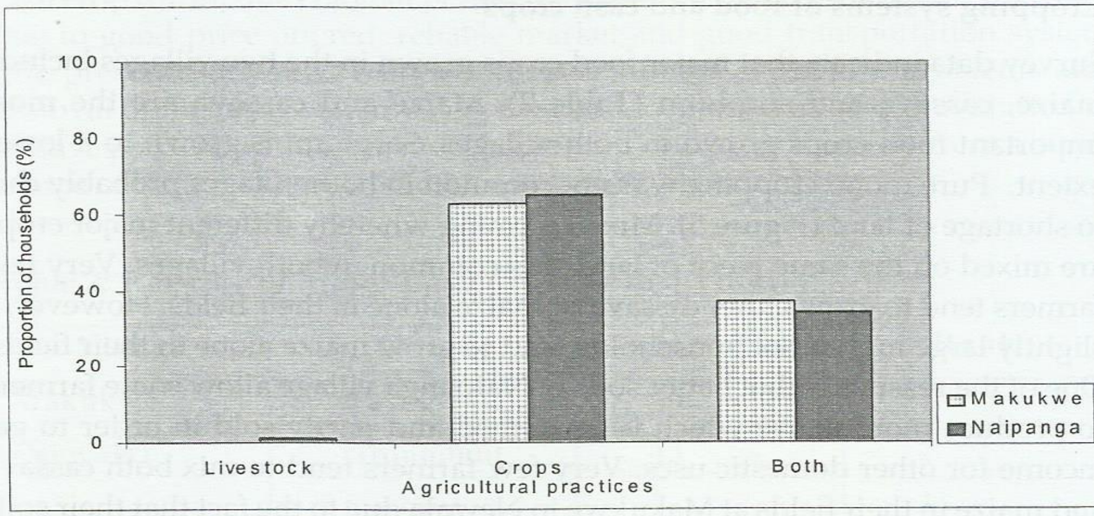

Figure 4: The Proportions of Main Agricultural Practices in Study Areas

With regards to the soil fertility management practices, residues from crops and livestock are the major source of soil nutrients. Immense measures need to be taken to strengthen the application of organic residues on soils.

Issues of concern affecting livelihoods of people

There are a number of issues that affect the livelihoods of people in various places in the country. Since the majority of people in Tanzania live in rural areas where most of them depend upon agriculture for their livelihood (URT, 1997), understanding their major problems is important in formulating different strategies aimed at developing agriculture and improving their income generating capacity. These are issues also regarded to contribute to poverty in the study areas. Broadly, major development constraints in study areas include;

- Food shortage attributed to drought, unreliable rainfall and poor or declining soil fertility
- Poor health services
- Lack of agricultural inputs such as sulphur, fertilizers, pesticides, improved seeds of both food and cash crops
- Human diseases particularly malaria and HIV/AIDS infections
- Poor transportation systems
- Lack of sustainable water supply system
- Fluctuations of crop prices particularly cashewnut

Cropping systems of food and cash crops

Survey data indicate that major food crops grown in the two villages include maize, cassava and sorghum (Table 2). Maize and cassava are the most important food crops grown in both villages. Sorghum is grown to a lesser extent. Pure mono cropping was not common in both villages probably due to shortage of land (Figure 5). Mixed farming whereby different major crops are mixed on the same piece of land was common in both villages. Very few farmers tend to grow either cassava or maize alone in their fields. However, a slightly large number of households tend to grow maize alone in their fields. One of the reasons is that better soils in Naipanga village allow some farmers to produce more maize which is consumed and partly sold in order to get income for other domestic uses. Very few farmers tend to mix both cassava and maize in their fields at Makukwe in Newala due to the fact that their soils are very poor, drought prevalence is common in the area, leading to poor production of maize. However mixing cassava and maize is very common in Naipanga probably due to favorable agronomic conditions allowing for a better performance of the crops (Table 2). On the other hand, a proportion of farmers who tend to mix three or more crops on the same piece of land is high at Makukwe in Newala probably due to land scarcity attributed by large population (Likanda *et al.*, 1995). Mixed cropping system needs to be promoted since this can reduce risk of crop failure and make maximum use of the land resource.

Table 2: Cropping Patterns of Major Food Crops per Household (%) in the two Villages

Village	Cropping Systems			
	Cassava	Maize	Cassava/maize	Cassava/maize/sorghum
Makukwe (Newala)	7	1	10	80
Naipanga (Nachingwea)	0	10	64	26

Source: Survey data 2001

Table 3 indicates the ranking of different major cash crops and their importance to the livelihood of people in the study area. In both villages and at the same magnitude cashewnut is the most important cash crop. At Makukwe in Newala, groundnut becomes the second major cash crop while at Naipanga, cassava, which is also an important food crop, is the second major cash crop. Previous studies indicate that (Bennett *et al.*, 1979), groundnut was the major cash crop during the colonial period in Nachingwea. Its production was high due to good price offered, reliable market and good transportation system (the presence of railway line). However due to marketing problems and removal of the railway many people abandoned the crop and thus shifted to cassava production and sesame. The crops in both areas therefore form a major source of crop residues added into soils to improve fertility.

Table 3: Ranking of Major Cash Crops in two Villages

Village	Crops	Score (%)	Rank
Makukwe (Newala)	Cashew	46	1
	Groundnut	43	2
	Cassava	7	3
	Sesame	4	4
Naipanga (Nachingwea)	Cashew	49	1
	Groundnut	17	3
	Cassava	30	2
	Sesame	14	4

Source: Survey data 2001.

Access to land and Management

Land ownership

One of the major problems which affect agricultural activities in the southern areas of Tanzania is availability of land. However, most of the farmland available has been occupied by cashew trees, which were introduced in late 1950's. The tree can grow up to six meters high and can cover a diameter of twelve meters on the ground. If cashew trees are grown to a close spacing of less than nine meters (9 x 9 m) can result into overlapping of tree crowns that limit the cultivation of annual intercrops. This is a serious problem facing farmers in allocating land for different crops. It is sometimes difficult for them to decide whether to allocate all land for cashew since there are situations whereby cashewnuts sale cannot meet their needs due to poor price or poor production.

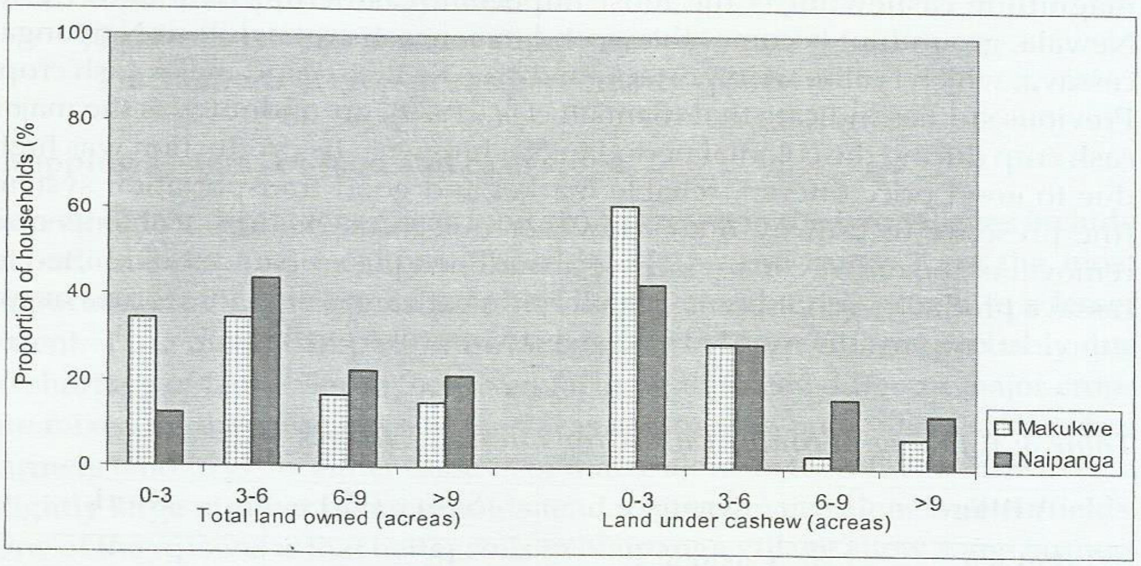

Figure 5: Average Acreage per HH and a Proportion of Land Under Cashew Farms

Figure 5 indicates that the maximum land under cashew farming system that can be owned by a single farmer is less than nine acres. The majority of farmers in both villages can hold less than 6 acres. Those who own between 0-3 acres are more in Makukwe than in Naipanga village and this suggests that the main producers of cashew in southern areas of Tanzania are small-scale holders. Any program that intends to promote cashewnut production must therefore formulate strategies applicable to small scale farming practices since there is no room for opening large farms due to land scarcity.

Soil Fertility Management Practices

Generally, farmers could easily recognize the status of their soils in terms of fertility through various common indicators such as changing in cropping pattern. For example, Table 4, suggests that the proportion of farmers who indicated that their soils are poor in fertility is nearly 35% and 60% in Naipanga and Makukwe respectively. The proportion of households indicating moderate soil fertility at Naipanga is larger than that of Newala who indicated that their soils are low in fertility (Table 4). Based on existing soil literature which indicates low soil fertility status in similar sites (Baker, 1995; Majule *et al.*, 1997; Majule, 1999), the findings from this study show that farmers are knowledgeable on issues related to soil fertility. It is important to make sure that sustainable soil fertility management strategies are developed in both areas since most of the people depend on agriculture for their livelihood.

Table 4: Farmers Perception on Soil Fertility Status in Fields

Village	Proportions of Respondents (%)		
	High	Moderate	Low
Makukwe	02	40	58
Naipanga	08	62	29

Due to their low inherent natural fertility, which is coupled by further degradation due to various reasons such as burning of crop residues and vegetation (Figure 6), excessive leaching, and acidification process associated with elemental sulphur dusting (Majule *et al.*, 1997) the productivity of these soils is threatened. In the two study areas, less than 10% (Table 4) recognized that their soils are low in fertility. The situation is worse at Makukwe in Newala. On the other hand even a proportion of land, which is moderate in soil fertility, is lower (nearly 40%) than at Naipanga (over 60%). Broadly, soil fertility through farmers was recognized to be lower at Makukwe than Naipanga (Table 4). These observations conform to geophysical observation made by previous researchers (Bennett *et al.*, 1979; Baker, 1995; Majule, 1999). Soils at Naipanga are characteristically reddish brown, clayey with a number of termite mounds, which suggests higher fertility status. On the other hand, soils at Makukwe in Newala are characteristically sandy in nature with light textured class indicating poorer fertility status. A further declining in soil fertility was reported to be associated with continuous cultivation on the same piece of land for a long period without fallow. Reasons for reduced fallow period has been associated with increased human population, utilizing fixed available land (Likanda *et al.*, 1995). Other reasons for declining soil fertility mentioned in both villages were lack of awareness on land resources management such as the importance of incorporating crop residues on soils, the effect of sporadic fire and shallow cultivation

The majority of people in both areas do not use artificial fertilizers in their fields with the exception of few (nearly 18%) in Nachingwea as indicated in Table 5. Nearly 30% of households tend to use FYM particularly from goat and cattle in both villages. Generally, the majority of people tend to improve their soils by using cheap and available organic residues from various sources. The application of crop residues is done in combination with other soil and water conservation practices common to them such as small tie ridging whereby crop residues are laid down in between two ridges and covered with soil. Short rains, which fall in September/October, tend to facilitate the decomposition of residues added.

Table 5: Major Inputs used in Managing Soil Fertility

Village	Proportions of Respondents (%)		
	Crop residues	Farm Yard Manure	Artif. Fertilizers
Makukwe	79	26	05
Naipanga	54	30	16

Other soil and water conservation practices mentioned were deep hoe cultivation as opposed to scratching of soils, which was practiced in the past. Broadly the proportion of people who use crop residues is larger at Makukwe than Naipanga (Table 6). A very small proportion of farmers use artificial fertilizers. Reasons for low use of both artificial fertilizers and FYM need to be investigated.

Effect of Organic Residues Additions on Growth of Maize and pH

The effects of plant residues on plant dry matter yields of maize grown under different levels of sulphur are presented in Figure 7. The effects of the sulphur on soil pH are shown in Figure 10.

Plant dry matter weight (Figure 7) was the lowest in the soil without any residue incorporated, while they were higher (significantly) upon incorporation of organic residues into soil. There were weight differences between the different residues, with pigeonpea and **cordia sp.** resulting in highest dry weights. This trend of plant heights was generally maintained in all subsequent levels of soil sulphur.

The better maize performance due to incorporation of organic residues implies the organic residues so incorporated improved soil chemical conditions to favor increased maize growth. Soil pH could be one of these conditions improved. The improvement of soil pH is attributed to the alkalinity possessed by the plant residues, which neutralized or counteracted the H^+ produced as the sulphur was oxidized in soil (Majule, 2001).

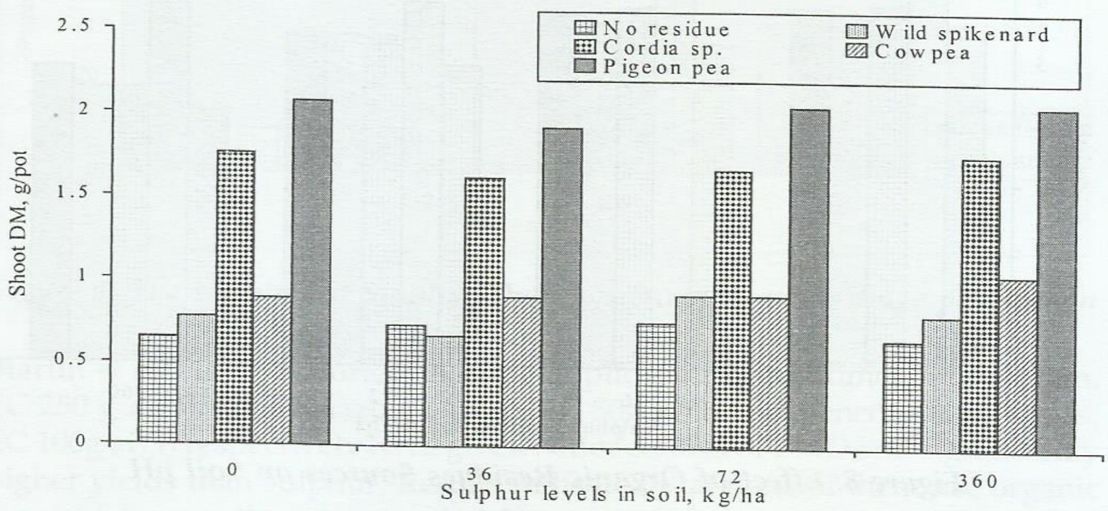

Figure 7: Effects of Organic Residues on Maize dry Matter Yields

The better maize performance (i.e. increased plant dry weight) in which pigeonpea and **cordia sp.** residues were incorporated implies a higher degree of amelioration of soil pH, which, in turn, indicates a higher alkalinity in these residues. *Cordia* spp in Makonde name is known as *Mtapuchi*. This is an interesting shrub which can grow up to four meters high. Wherever a farmer sees this plant, he/she will grow food crops in that area. On the other hand, wild spikenard is a traditional shrub that has been reported by farmers to be associated with high crop yields when incorporated into soils.

The present observations are in agreement with Tang and Yu (1999) who showed that plant residues incorporated in acidic soils increased soil pH and that the magnitude of the increase was positively correlated with the concentration of excess cations i.e. potential alkalinity in the plant materials.

Similarly, Noble *et al.* (1996), Sakala (1998), Majule (1999) and Tang *et al.* (1999) observed that increased soil pH was correlated with ash alkalinity of plant residue added. Thus, some scope exists of choosing those organic materials with high alkalinity for the purposes of ameliorating soil acidity which could come about from use of sulphur as it is practiced in Mtwara.

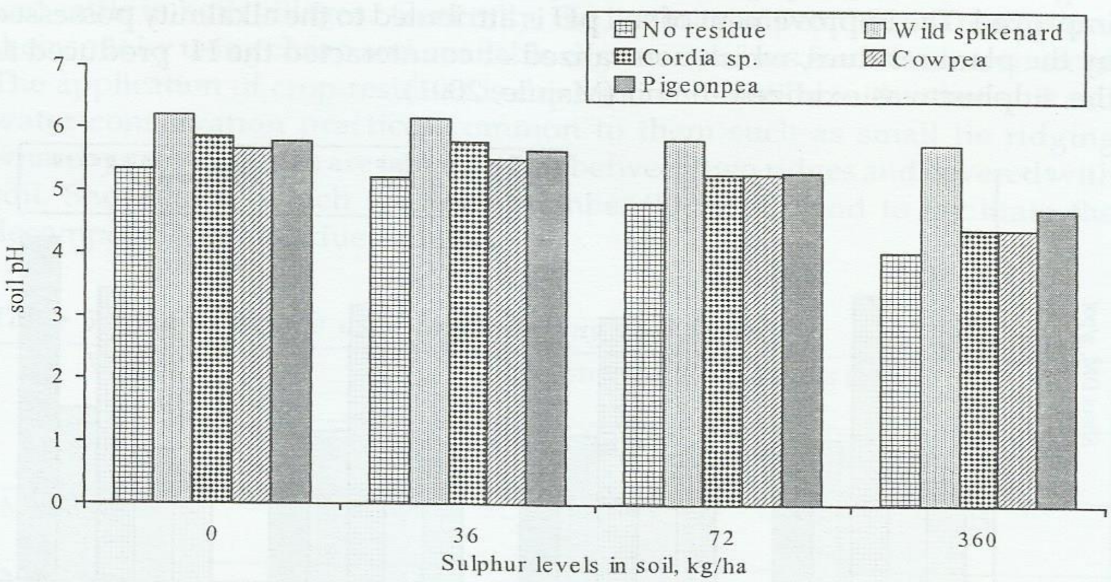

Figure 8: Effect of Organic Residues Sources on Soil pH

The high soil pH in which organic residues were incorporated than in the control soil indicates the role of the residues in raising the soil pH (Figure 8). The different soil pH values under different residues has been reported to be related to the residue alkalinities and chemical composition of the organic residues (Sakala, 1998; Majule, 1999). The generally lower soil pH in soil containing 360 kg S/ha implies that oxidation of larger quantities of sulphur led to production of more intense acidity all of which could not be neutralized by the residues. Incubation experiment therefore confirms that there is a need to characterize more organic residues sources and ensure that farmers use them in improving soil fertility.

Application of elemental sulphur

One of the driving forces for this research was a concern about the environmental effect of elemental sulphur dust on soils particularly the acidification processes reported to aggravate declining soil fertility (Majule *et al.,* 1997). This is a threat to sustainable cashewnut production in the country since the crop is equally economically important to small-scale growers as to the nation.

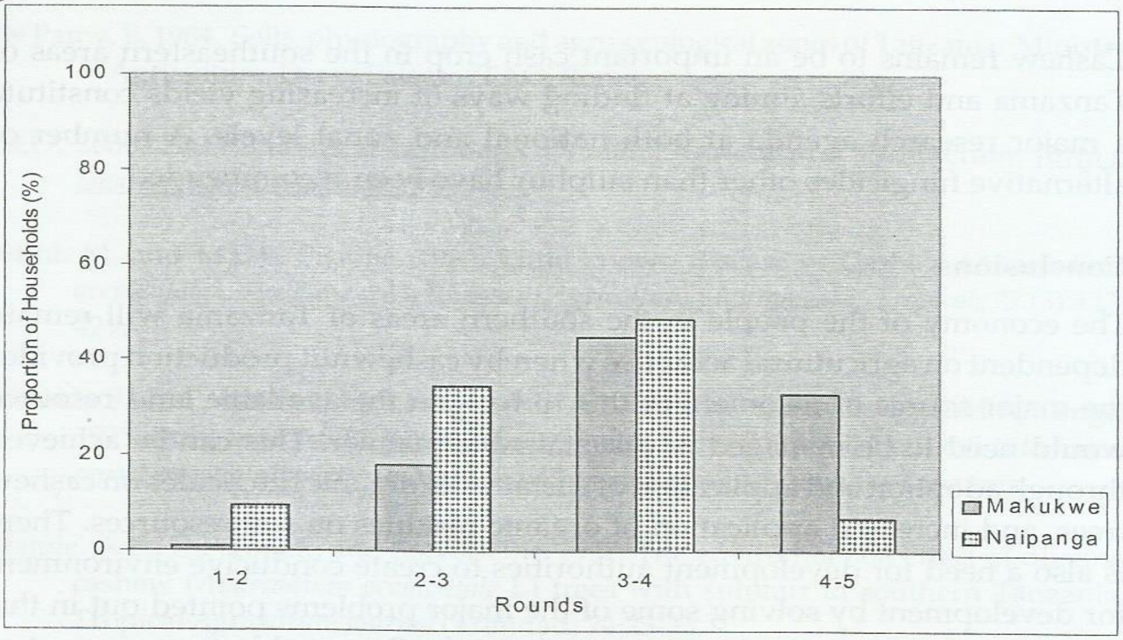

Figure 9: The Number of Sulphur Dustings (rounds) per Village per Season

Martin *et al.* (1997) reported that the application of triadimenol (Bayfidan, EC 250 g ai/l), haxaconazole (Anvil, EC 50g ai/l) and penconazole (Topas, EC 100g ai/l) respectively have given better control of PMD and significantly higher yields than sulphur. Results indicated that none of them use organic fungicides currently recommended. However, farmers are still using elemental sulphur, but at different numbers of rounds, probably due to lack of capital to dust all five rounds recommended (Figure 9). Most of them tend to dust between 3-4 rounds, which appears to give yields comparable to yields obtained from trees dusted with 5 rounds of sulphur. An investigation of the effective application rounds is therefore still needed. Under targeted sulphur application it is possible to control the disease by applying it in very small amounts.

There are now a number of scientific reports which indicate that the application of relatively large quantities of elemental sulphur on cashew trees tends to acidify soils under cashew. The magnitude of acidification depends on the following key factors;

- Physio-chemical characteristics of soils
- The amount of elemental sulphur reaching the soil after dusting
- Management of soils such as organic residues additions

Cashew remains to be an important cash crop in the southeastern areas of Tanzania and efforts aiming at finding ways of increasing yields constitute a major research agenda at both national and zonal levels. A number of alternative fungicides other than sulphur have been recommended.

Conclusions

The economy of the people in the southern areas of Tanzania will remain dependent on agricultural activities whereby cashewnut production provides the major source of income. For this to happen the available land resource would need to be managed in a sustainable manner. This can be achieved through adoption and application of sustainable organic fungicides on cashew trees, and increased application of organic residues on soil resources. There is also a need for development authorities to create conducive environment for development by solving some of the major problems pointed out in this study, which affects the livelihoods of people. Sustainable management of land goes with proper land allocation particularly to the youth. The current system whereby elders own large pieces of land tends to impinge upon proper management of land due to the fact that elders are not capable of managing properly their land. Land scarcity to the young tends to encourage out migration, which reduces a vital manpower to do fieldwork.

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