UTILIZATION OF SOIL FERTILITY MANAGEMENT KNOWLEDGE AMONG SMALLHOLDER FARMERS IN CHAKOL DIVISION, KENYA

By

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DECLARATION

This thesis is my original work and has not been presented for a degree or any other award in any other university.

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This work is dedicated to my beloved parents Mr. John and Mary Murua and to my beautiful sisters Kate, Anne and Krissy. Your prayers, understanding and unwavering support made it possible to complete this study.

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ABBREVIATIONS AND ACRONYMS

BNF	Biological Nitrogen Fixation
FEI	Folk Ecology Initiative
FGD	Focus Group Discussion
FYM	Farm Yard Manure
ICRAF	World Agroforestry Centre (International Centre for Research in Agroforestry)
ISFM	Integrated Soil Fertility Management
KARI	Kenya Agricultural Research Institute
KWAP	Kenya Wood-fuel and Agroforestry Project
MoA	Ministry of Agriculture
N	Nitrogen
P	Phosphorus
PM&E	Participatory Monitoring and Evaluation
RF	Resource Farmer
SPSS	Statistical Package for Social Scientists
SSA	Sub-Saharan Africa
TSBF-CIAT	Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture

ABSTRACT

This study investigated soil fertility knowledge and how it influenced the selection and effective use of various soil fertility technologies among smallholder farmers in Chakol Division of Teso District in western Kenya. Chakol Division has a high population density of approximately 427 persons per km^2 while absolute poverty levels for the district stand at 56%. Poverty levels have been worsened by poor agricultural production while continuous cropping of land with little restoration of soil nutrients through application of organic manures and mineral fertilisers have contributed to the increase of soil degradation over time. The need to improve agricultural productivity through better soil fertility management is therefore paramount considering that Teso District mainly relies on agriculture with 65% of the population being involved in agricultural activities. In order to address this problem, a call for a holistic approach that is socially acceptable hence easily adaptable and fit for purpose is necessary and therefore the conception of the Integrated Soil Fertility Management (ISFM) strategy. This ISFM strategy at TSBF-CIAT aims to maximise on nutrient recycling on farms, replenish soil nutrient pools, reduce soil nutrients losses to the environment and improve the efficiency of external inputs. It was applied through the Folk Ecology Initiative (FEI) approach which attempted to strengthen farmers' understanding of soil fertility management through community-based interactive learning. This current study grew out of the FEI approach and it involved both quantitative and qualitative data collection techniques using questionnaire surveys, focus group discussions and in-depth interviewing. A total of ninety smallholder farmers and five key informants were interviewed while six FGDs involving thirty six farmers were carried out. SPSS was used to analyse the data collected through questionnaires and a narrative log used for the case studies. Study findings showed that farmers in Chakol had knowledge on the preparation, benefits and drawbacks of soil fertility technologies but the decisions they made towards the selection and application of technologies such as compost, natural fallows, cereal-legume rotation, biomass transfer and fertiliser were mostly affected by capital, land, labour and other social constraints. Preference was given to technologies such as farmyard manure and crop residue incorporation since they were socially convenient in terms of labour and time demands; were comparatively less complicated to apply, cheaper and easier to get. However, less accessible technologies such as mineral fertilisers, no matter how important, were least preferred or selected. It is therefore concluded that soil fertility knowledge is necessary for meaningful decision making. It played a vital role in the selection and application of soil fertility technologies. However, poverty played a major constraining role. It is therefore recommended that strategies to boost farmers' incomes should be strengthened. For instance, through encouraging farmers to form marketing groups and linking them to markets to generate incomes that can then be ploughed back in the recapitalisation of the local degraded soils. Alternative livelihood sources to cultivation such as bee-keeping should also be encouraged. Such enterprises as bee-keeping require lesser labour, land and capital and can therefore be profitably carried out in spite of the decreasing land sizes.

CHAPTER ONE

1. INTRODUCTION

1.1 Background to the Problem

Agriculture is the major sector on which two-thirds of the over 750 million people living in rural areas depends (Diagana, 2003; Thirtle, Lin, and Piesse, 2003). Unfortunately agricultural productivity in most of the region has been stagnant or declining (Nkoya et al., 2008).

Poverty and soil degradation have been cited as major problems that affect agricultural production in sub-Saharan Africa (SSA) (Nkoya et al., 2008). About 41 percent of the population in SSA (more than 300 million people) lived on less than US$1 per day in 2005—the highest poverty rate of any region of the world (World Bank, 2007). In addition, soil fertility degradation is widely acknowledged as a major factor limiting productivity of the sub-Saharan African smallholder farming systems (Franzel 1999; Sanchez et al., 1997; Tarawali et al., 1999; Mairura et al., 2008). This degradation is particularly important in areas where rapid population growth, continuous cropping and restricted use of organic inputs and mineral fertilisers have led to low productivity of the systems (Ojiem, 2006).

According to the Boserup Model on intensification, an increase in population density or land scarcity is an independent variable that can trigger agricultural intensification (Netting, 1993; Winfrey & Darity, 1997; Stringer & Reed, 2007). If populations grew and people could not move to areas where resources were still plentiful, they would have to increase the amounts and the predictability of the food they produced from a limited area (Ibid.). In the past, soil fertility management practices in SSA mainly encompassed natural fallowing, shifting cultivation and slash and burn. Over the last 50 years, high population densities have rendered these practices impractical and have necessitated the introduction of mineral fertilisers, construction of terraces, efficient use of livestock manure, improved fallows and compost (TSBF, 2001). In SSA, high fertiliser use efficiency has not been achieved and access to mineral fertiliser by smallholder farmers is increasingly becoming elusive with increasing poverty levels. It is therefore clear that there is need for rapid strengthening of organic sourcing of plant nutrients in smallholder farming systems. However, making changes in smallholder farming practices presents challenges, economically, socially and ecologically. In addition, for agricultural communities to restore soil fertility, adapt to and benefit from these changes requires some fundamental knowledge of new agricultural practices (TSBF, 2001)

Knowledge is bound up with action but what people do is not necessarily what they ‘know’. In addition, not all knowledge held by farmers is put into action. (Scoones, et al., 1994; Batterbury, 1998). This can be due to the fact that different knowledge types represent certain conceptions and convictions, therefore the issue of farmer preferences, furthermore, farmers’ resources such as land, labour and capital can also be limiting. It is therefore paramount to empower farmers through greater understanding and application of soil fertility management principles (Bationo, 2003).

Judicious decisions can only be made based on the knowledge held. Therefore, strengthening farmers' knowledge is an important step in encouraging improved soil fertility management. This is only likely to be successful when researchers and extension officers first gain in-depth understanding of the farmers' knowledge and their production goals. Farmers are only likely to adopt sound soil management if they are assured of returns on their investment. Therefore the use of the Integrated Soil Fertility Management (ISFM) approach has been preferred by researchers. ISFM can help low resource endowed farmers to optimise their production potential through the incorporation of a wide range of adoptable soil fertility management principles, practices and options and consequently mitigating the problems of food insecurity and land degradation (Kimani et al, 2003).

1.2 Problem Statement and Justification

Teso District relies heavily on agriculture with 65% of its population being involved in agricultural activities and 56% living in absolute poverty (Republic of Kenya, 2005). Despite this, agricultural production in Chakol Division, Teso District is low due to a decline in soil fertility. This was made worse by the high population growth rate with Chakol ranked as having the highest population density (approximately 427 persons per km^2) in the district (Ibid.).

Soil fertility decline and land scarcity in this area was underlined by the encroachment into natural habitats for wild animals and the burning of forests and bushy lands on the slopes of hills and subsequently the cleared lands cultivated for agriculture. Soil fertility decline in Chakol was also exacerbated by soil erosion on cleared fertile areas and more so on sloping farms where no terraces or stone barriers had been constructed. In addition, the likelihood of soil erosion measures being put in place was complicated given that many of the cultivators of the cleared plots did not own those plots (TSBF, 2002). Past studies have also shown that farmers in Chakol believed that their farms were still generally fertile, and therefore they did not apply farmyard manure and mineral fertiliser (TSBF, 2002).

Land changes, both natural and anthropogenic, are increasingly causing concern among scientists and farmers due to the resulting decline in soil fertility in the highlands of Eastern Africa (Sanchez and Leakey, 1997; Sanchez *et al.*, 1997; Wickama and Mowo, 2001; Girmay et al., 2008) and elsewhere in sub-Saharan Africa (SSA) (FAO 2001). It is out of this concern that TSBF-CIAT partnered with smallholders through the Folk Ecology Initiative (FEI), to apply community-based interactive learning for soil fertility with regard to ISFM. It therefore introduced various soil fertility technologies while integrating the local knowledge from the farmers. In doing so, it was clear that farmers had deep soil fertility management knowledge. However, this deep knowledge did not, as expected, translate into adaptive practices hence continued soil degradation and consequently decreased agricultural productivity, leading to increased poverty levels. In line with this, this study sought to determine the factors that hindered the effective application of soil fertility knowledge in Chakol and what role this knowledge played in the selection and application of soil fertility technologies. To achieve this, a comparative approach between farmers who participated in the FEI and non-FEI participants was taken to analyse the relationship between knowledge and soil fertility management. FEI participants were considered to have strengthened their local knowledge with that from the researchers, unlike their counterparts who were believed to rely more on their local knowledge. These two groups were probed on their understanding of various soil fertility technologies, their reasons for use or disuse, method of application and the benefits they expected.

1.3 Research Questions

The study sought to answer the following research questions

i. What is the role of soil fertility knowledge on the selection of soil fertility management technologies among smallholder farmers?

ii. What is the role of soil fertility knowledge on the application of soil fertility management technologies among smallholder farmers?

iii. What is the role of the various knowledge networks in the selection and utilisation of soil fertility management technologies and practices?

iv. What is the influence of the Folk Ecology Initiative (FEI) on the management of soil fertility in Chakol?

1.4 Research Objectives

The main objective of this study was to assess the impact of soil fertility knowledge on the application of fertiliser technologies by studying the rationale for smallholder farming practices in Chakol Division. This study sought to determine whether knowledge led to more informed selection of soil fertility technologies and efficient utilisation for increased food production. The following are the specific objectives of the study:

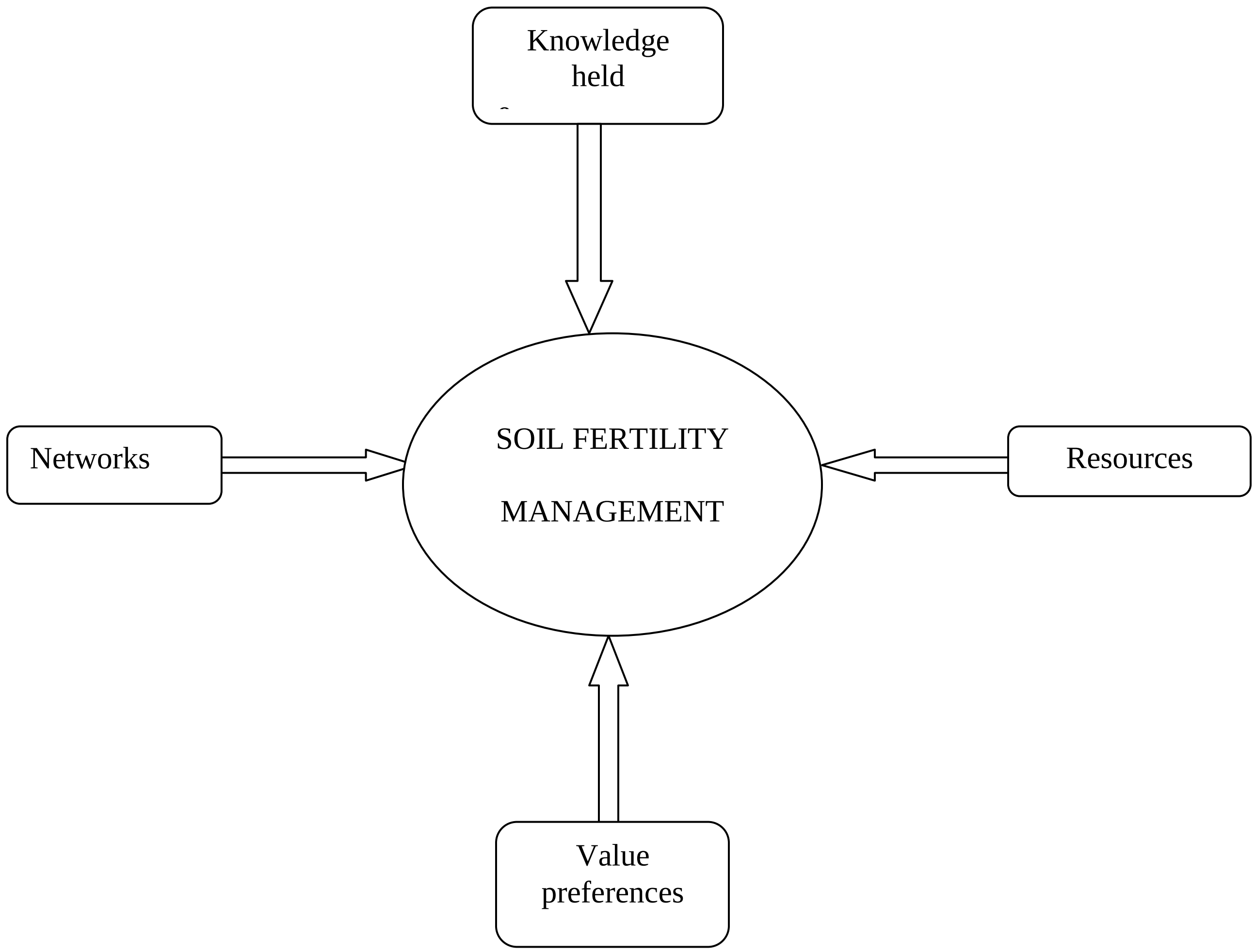
i. To establish the role of knowledge on the selection of soil fertility technologies among smallholder farmers.
ii. To investigate the role of soil fertility knowledge on the nature of application of soil fertility management technologies
iii. To evaluate the importance of different knowledge networks in the selection and implementation of soil fertility management practices.
iv. To explore the influence of the Folk Ecology Initiative (FEI) on soil fertility management in Chakol.

1.5 Significance of the Study and Anticipated Output

This study is a contribution to the knowledge on soil fertility management among farmers in Chakol Division. Through the understanding of how knowledge and knowledge networks influenced fertiliser selection and utilisation, the study helped to assess the impact of the FEI in Chakol. The research findings will ultimately contribute to meeting TSBF-CIAT's strategy of using ISFM research in understanding and seeking to manage the processes that contribute to changes in soil fertility.

1.6 Conceptual Framework

Farming populations are essentially heterogeneous in terms of the strategies adapted to solving problems leading to differences in farm management styles. Embedded in this processes is agricultural knowledge and how it is applied in agricultural practices. The decisions that the farmer makes in farm management are based on value preferences, available knowledge, resources and networks, and land degradation in the form of declining soil fertility can only be managed by the efficient application of these variables.



Source: Author, 2007.

Figure 1.1: Soil Fertility Conceptual Framework

1.7 Limitations of the Study

The respondents were dispersed and the researcher had to walk long distances to access them. Due to time and financial constraints on the part of the researcher, re-sampling had to be done to replace those farmers that were unavailable during data collection. In addition, this constraint also limited probing widely into the impacts that the FEI had in Chakol Since this study was a follow up of the FEI, there was a tendency among few farmers to give answers aimed to please the researcher rather than engage into objective discussions. In order to overcome the above limitations, in depth FGDs were carried out with the most knowledgeable farmers to gain more insight into the reality and to make clear any inconsistencies.

1.8 Definition of the analytical concepts

Folk Ecology Initiative (FEI): This was a community-based interactive learning approach with specific application to integrated soil fertility management (ISFM) at the Tropical Soil Biology and Fertility Institute (TSBF). The FEI sought to strengthen farmers' understanding of soil fertility management through interactive learning by researchers and local farming communities in Western Kenya (TSBF, 2001).

Integrated Soil Fertility Management (ISFM): It is the holistic approach to soil fertility research that embraces the full range of driving factors and consequences of soil degradation – biological, physical, chemical, social, cultural, economic and political. It aims to replenish soil nutrient pools, maximise on farm recycling of nutrients, reduce nutrient losses to the environment and improve the efficiency of external inputs (CIAT, 2005).

Knowledge Networks: This refers to sets of direct and indirect relationships and exchanges which may be interpersonal, inter-organisational or socio-technical (Mango, 2002) and which act as sources of knowledge or knowledge dissemination.

Resource Farmer (RF): Refers to a local farmer who was selected by the farming community in Chakol to act as a link between them and researchers. The RF was very knowledgeable in agricultural matters and had good rapport with both the local farmers and researchers hence he could be consulted by farmers on soil fertility management.

1.9 Organisation of the Thesis

The chapter that follows deals with literature review on soil fertility and land degradation in smallholder farms from various sources. It gives an overview of the situation from a global, regional and finally to a local perspective in Chakol. It also highlights on the effects of land degradation, the mitigation measures that have been put in place and some of the recommendations provided by various authors. Finally it gives an insight into the role of knowledge and knowledge networks in the selection and use of soil fertility technologies.

Chapter Three covers the methodology. This depicts the systematic way in which the sampling and data collection was carried out during the study to obtain information from various categories of respondents.

Chapter Four is about the study findings and discussion. It pulls together the theoretical threads of the thesis and the summaries of the main findings on the level of uptake of soil fertility technologies and their sources. It also discusses the influence of knowledge especially from the FEI on the selection and adaptive use of new soil fertility management technologies in the study area of Chakol. The findings are presented as frequencies and percentages, tables and charts.

The last chapter ties the thesis together. It is a discussion of the major findings from both the literature review and primary data. This chapter then ends with a conclusion and recommendation.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Introduction

This chapter deals with soil fertility matters and the complexities involved in its management. It also tries to capture soil fertility knowledge issues and the role that it plays in the management of soil fertility. First is an overview of land degradation in form of soil fertility depletion in smallholder farms. It maps out the causes of this decline, its impact on food production and some of the interventions that have been put in place so far such as the Integrated Soil Fertility Management (ISFM) strategy through the Folk Ecology Initiative (FEI). This chapter goes further to state why these interventions did not have impact to the desired extent and tries to provide recommendations. Literature on the indicators that farmers use to assess soil fertility on their farms and the various strategies they use to manage fertility decline on their farms is also reviewed here. Finally, this chapter highlights the role that knowledge networks play in the dissemination of soil fertility knowledge and in the decision making of the type of soil fertility management technology to be implemented by smallholder farmers.

2.2 Overview of Smallholder Soil Fertility and Land Degradation

Human–induced soil degradation has affected 15% of the total global land area (Bationo et al., 1998; UNDP, 2000) and 65% of Africa’s arable soils (Sivakumar and Wills, 1995). Land degradation manifested in the form of soil fertility depletion especially under the smallholder farming sector is one of the root causes of declining per capita food production in Africa (Stoorvogel & Smaling, 1990; Lal, 2010). In SSA, this decline is from 150 in 1960 to 120kg per person in 2005 and is projected to decrease drastically by 2030 (Lal, 2010). Emerging evidence attributes this to insufficient nutrient inputs relative to exports primarily through harvested products, leaching, gaseous losses and erosion. This has resulted in yields that are about 2 - 4 times lower than the potential per capita food production (Bationo, 2003).

The biophysical social and economic heterogeneity that characterise SSA smallholder farming systems are major hindrances to the widespread application of adequate and better solutions to combat nutrient depletion (Ibid.). In western Kenya, for instance, over 70% of the farmers are smallholders who have low crop productivity due to low soil fertility and limited financial resources to buy inputs (Okwusa, et al., 2006). High cost of fertiliser has led to its infrequent and low application which cannot improve and sustain productivity whereas organic inputs such as animal manures are available though in limited amounts and low in quality (Ibid.).

Generally, soils in Kenya are characterised by inherently low nitrogen (N) and phosphorus (P). In addition, land with a high agricultural potential is densely populated and most households of 5-8 persons nowadays have less that 1 ha to grow their crops (Smaling, 1993). In semi-arid areas, farmers have more but less productive, fragile land (Ibid.). In western Kenya, population growth has contributed to the gradual depletion of nutrients through exports in crop products, leaching and soil erosion for which farmers have been unable to compensate via organic resources or mineral fertilisers (Shepherd and Soule, 1998).

Extension in most of Africa (Kenya being no exception) has tended to be prescriptive and input driven focusing primarily on the use of hybrid maize and mineral fertiliser through blanket recommendations (Bationo, 2003). Little success has resulted from this and although farmers recognise soil fertility as a primary constraint to food production, they consider mineral fertiliser to be a substitute for rather than a complement to other land husbandry practices. This threatens the long-term sustainability of their production systems (Ibid.).

Successful interventions that will aid the process of bringing about change to the current soil depletion status go beyond direct technical interventions. It is imperative to recognise that long-term soil fertility improvement requires an evolutionary process and a participatory research and development focus which broadens the approach away from a purely technical focus. Nutrient deficiencies in Western Kenya are multiple and thus require a cocktail of techniques in which synergies can occur and agroforestry technology for example, has a major role to play in providing alternatives to the sole use of mineral fertilisers' (Mango, 2002). In addition, the need to strengthen the knowledge on soil processes for the farmers, the researchers and extension officers is necessary in the improvement of soil fertility management (Bationo, 2003).

2.3 Soil Fertility Indicators and Management Technologies

Farmers in western Kenya rely on various indicators to assess soil fertility. Such indicators include, yield, soil colour, compactness, soil odour and the composition of the vegetation (Mango, 2002: Odendo et al., 2010). After a period of continuous cropping, these indicators change. For example, the soil colour transforms from dark red to brown, the odour disappears and the flora changes indicating soil fertility decline.

To restore soil fertility one of the options includes the use of manure and mineral fertilisers. However just like in many parts of sub-Saharan Africa, the use of animal manure in western Kenya is limited because the quantities available on farms are often insufficient to maintain soil fertility (Jama et al., 1997), while the use of mineral fertilisers is constrained by unreliable returns (Ruthenberg, 1980; Anderson, 1992; Odendo, 2009), limited access to capital by smallholders (Hoekstra and Corbett, 1995), and unreliable markets for agricultural produce (Hassan et al., 1998; Paswel, 2009).

The other alternative to restoring soil fertility is the use of legumes to incorporate N into the soil via biological N_2-fixation (BNF) and residue incorporation. However this requires an integrated soil fertility management (ISFM) strategy since phosphorus (P) which is important for effective N_2-fixation through promotion of nodulation has to be acquired from elsewhere (Giller, 2001). Another limitation is that the current knowledge on N_2-fixation performance under the non-ideal conditions encountered in African smallholder farming systems is also limited. N_2-fixation is a high energy and water requiring process for the fixing plant (Raven, 1985; Schulze, 2004). Thus in semi-arid regions where nutrient and water shortages are common, these high requirements may limit the maximum yield potential for N_2 fixing plants. However, for smallholder farmers, the choice of the legume crop to use is determined by the ease in selling and the labour it demands. Generally preference is given to less complicated to apply and low labour demanding legume varieties. However a labour intensive legume crop may be selected if it generates immediate or assures high returns (Misiko, 2007).

Organic materials such as compost and green manures, on the other hand, differ significantly in their ability to provide nutrients to the soil and crop depending on the relative proportions of lignin, metabolic carbohydrates, cellulose and the presence of modifiers such as polyphenols which determine the rates of decomposition and nutrient release (Mafongoya et al., 1998). Biomass transfer of green manures are greatly limited by labour supply and also by small farm sizes which limit the extent to which niches can be found to produce the manures (Misiko, 2007). According to Netting, (1993), the dynamic process of continual adjustment between the numbers and skills of household members and the agricultural resources to which they have access is particularly important among intensive cultivators. It is apparent that smallholders everywhere strive to strike some kind of economic balance between household numbers and land size.

Other factors for the limited use of green manures include the unwillingness of farmers to forego a season to plant inedible species especially due to the land shortage problem, cost involved to buy seeds and inadequate information on their long-term benefits. A study carried out under the FEI project in western Kenya revealed that the quality of compost depended on the type of materials available on a given farm and on the type of knowledge that each farmer held (TSBF, 2001).

2.4 Integrated Soil Fertility Management (ISFM) Approach in Soil Fertility Management

Integrated Soil Fertility Management (ISFM) is the adoption of a systematic, conscious, participatory and broad knowledge intensive holistic approach to soil fertility research that embraces the full range of driving factors and consequences of soil degradation-biological, physical, chemical, social, economic and political (CIAT, 2006; Kimani et al., 2003). It aims at offering wide-ranging solutions that are socially acceptable and practical in the management of soil fertility (Misiko, 2007).

In order to provide improved and sustainable soil management practices, TSBF-CIAT came up with a research for development approach based on the ISFM paradigm called the Folk Ecology Initiative (FEI). Through FEI, TSBF-CIAT aimed to incorporate scientific insights developed by scientists into ecological and practical knowledge for farmer's decision making and choices.

According to the findings of a study done under the FEI in Chakol, farmers were found to possess deep knowledge about soils: their classification, utilisation and management. However, this deep knowledge held by farmers did not, as expected, inevitably translate into adaptive practices. This therefore forms the background to this study which seeks to better understand the relationship between smallholder farmers' knowledge and understanding and determinants of the choices made when selecting and utilising fertiliser inputs.

2.5 Knowledge, Knowledge Networks and Decision Making

Knowledge is essentially a social construction that results from a particular context and is being reshaped by the encounters and discontinuities that emerge at the points of intersection between actors life worlds (Long and Villareal, 1993). Knowledge is not just meant to meet a certain objective but it also contains social values i.e. knowledge is prescriptive and different knowledge types represent certain conceptions and convictions, including how farming should be carried out (Mango, 2002). In addition, farmers' practical knowledge about the local natural resources and how these resources interact is reflected in their farming techniques and in their local skill in using these resources to gain their livelihood (Reijntjes et al., 1992; Odendo et al., 2010).

The local knowledge of a farming population living in a specific area is derived from the local peoples' past farming experience; that handed down from previous generations and that of the present generation. Local knowledge is therefore not static. Traditionally, information was disseminated communally and the government did not have a role in provision of services like agricultural extension (TSBF, 2001). Farmers learned mainly through observation, apprenticeship and experience, resources were abundant and knowledge on the environment was extensive. New techniques developed by a member of the community or introduced from outside, if locally beneficial, spread by word of mouth, imitation or informal education in village meetings, initiation rites etc. and became part of the local knowledge (Reijntjes et al., 1992; Mango, 2002). When a technology developed elsewhere has been incorporated by local farmers as an integral part of their agriculture, it is as much a part of their local knowledge as self-developed technologies. Today, farmers have additional sources of information such as researchers and agricultural extension officers and they have more but not sufficient knowledge to do sustainable intensive farming. In addition, they are constrained in resources such as land, biomass and livestock (TSBF, 2001).

Changes in farming practices are likely to be observed with the acquisition of knowledge This may involve farmers taking up introduced technology, merging their local knowledge with the introduced one or redesigning or substitution of some aspects of the introduced technology with what is available to them. The ability to shift attention to different practices suggests that humans are continually monitoring their environment for matters of immediate importance, unconsciously processing, to some degree, a variety of information (Yohannes and Galaty, 1993; Beckford, 2002). In order for agricultural communities to restore their environments especially soil fertility, adapt to and benefit from the changes fundamental knowledge of new agricultural practices is required (TSBF, 2001).

It should be noted however that acquisition of knowledge does not guarantee its application. People's ability to make use of information depends on the degree of their processing mechanisms (Yohannes and Galaty, 1993; Beckford, 2002). There are two types of processing mechanisms; the unconscious processing mechanism which underlies routine decisions and it is therefore outside of a decision-maker's ordinary attention and awareness while the second is the conscious processing which involves long-range planning and critical thinking (Yohannes and Galaty, 1993; Austin, Pounds and Bailey, 2001). However, the larger the amount of information subjected to critical or conscious thinking, the more likely that it will be put into practice (Ibid.). Critical thinking is observed during decision making when some farmers take considerable time to explore possibilities and carefully integrate knowledge from various sources. Household decisions are the result of interaction between non-physical resources such as information, experience, knowledge and institution and physical resources such as land and labour (Yohannes and Galaty, 1993; Willock et al., 1999). In this decision-making process, discussions with trusted peers in comparable circumstances often play an important role.

Information processed and experience acquired, contribute to skill that is the driving force of the actions of decision-makers (Yohannes and Galaty, 1993; Willock et al., 1999). Therefore apart from adaptations of introduced innovations from elsewhere, farmers may make careful observations and small scale trials of new ideas (Reijntjes et al., 1992; Beckford, 2002).

Farmers have a remarkable, self-interested, creative capacity for local technology development. The development challenges require that we support the farmers' capacity to effectively make better use of their knowledge about their environment (Reijntjes et al., 1992; Davies et al., 2010.). In addition, it is important to strengthen their experimental and creative abilities to develop solutions and to effectively link them with agricultural scientists for the successful development of site specific techniques for sustainable agriculture.

CHAPTER THREE

3. STUDY AREA AND METHODOLOGY

3.1 Introduction

This is a methodological chapter that gives an overview of the study area, the research methodology and the methods that were used to collect data in the study. This chapter then concludes with the data analysis and the ethical concerns that were put in mind during the study.

3.2 Background of Study Area

3.2.1 Site characterisation

The study was carried out in Akites and Aludeka Sub-locations of Chakol Division in Teso District, western Kenya.

Chakol lies between a latitude of 00^0 57’ 99.8’’ N and longitude of 034^0 19’ 00.7”E. It has an undulating topography with a hilly terrain and a ground elevation of 1155 m above sea level. It receives an annual mean rainfall of between 1270mm and 1600mm distributed twice a year with the temperatures ranging between 14^0c and 30^0c. The long rains are received between late March and late May while the short rains fall from August to October (Maitima et al., 2005).

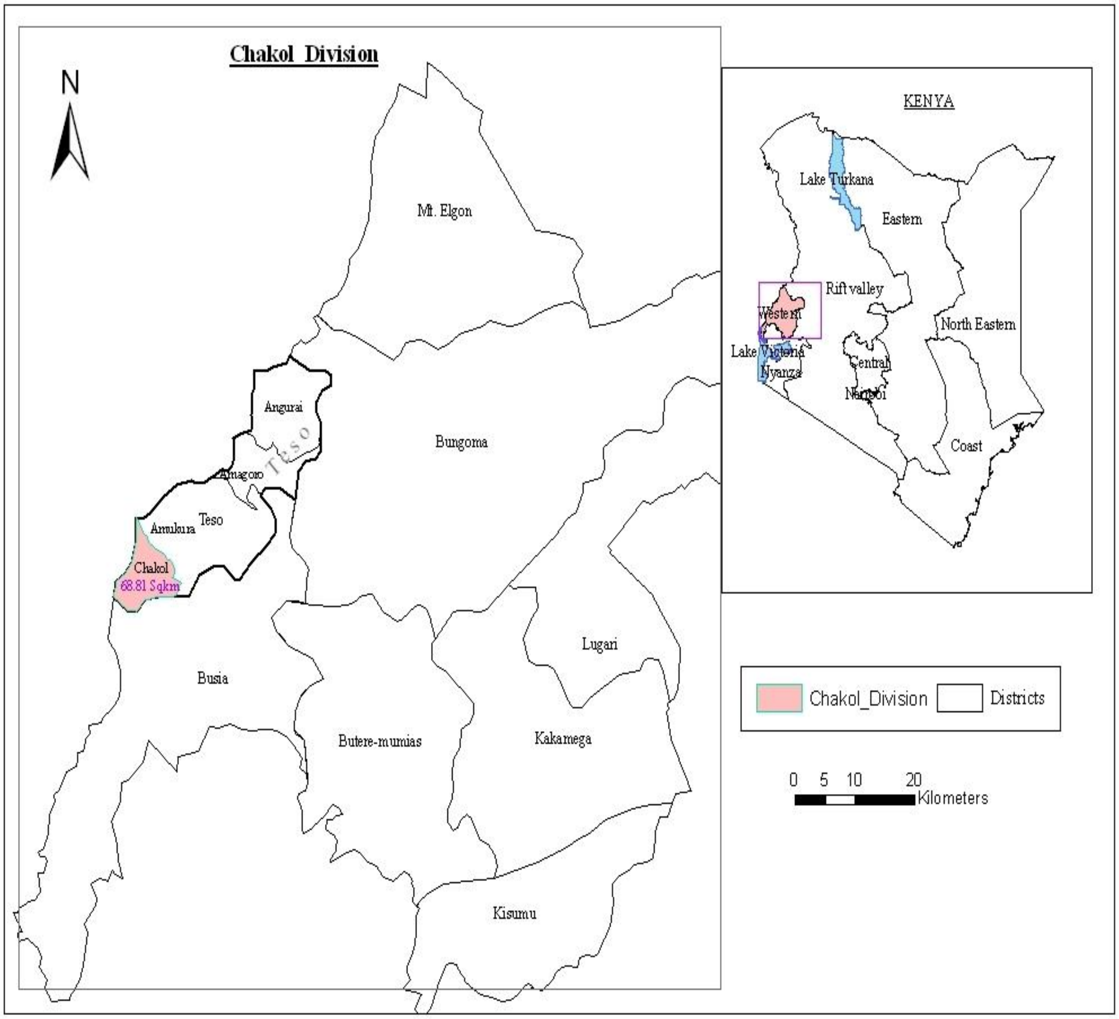


Figure 3.1: Map of Chakol Division, Teso District, Kenya

The soils can be characterised as dystric and humic Cambisols and most of them are sandy. Some are deep with some areas having porous rocky basements. The most common crops in the area include cassava, millet, sorghum, groundnut, sweet potatoes, common bean, and maize being the most stable food grown. Livelihoods in this community are mainly subsistent (Misiko, 2007).

3.2.2 The people

Chakol Division is predominantly inhabited by the Iteso people (also referred to as Teso, Itesot/Ateso) with a total population of 59,780 and a population density of 427 persons per km^2; which is the highest in Teso District (Republic of Kenya, 2005).

Linguistically the Iteso belong to the Teso-Karimojong branch of Eastern Nilotic languages (Karp, 1978). They are related to the Turkana with whom they have a similar common language and also belong to a common tribe with the Karimojong and the Kumam (Were, 1967).

3.2.3 Economic activity

The Iteso originally engaged in agriculture and not pastoralism like their linguistic relations. Only later did they acquire cattle (Fedders and Salvadori, 1979). Cattle are however an important nexus of value for the Iteso as a source of bride wealth, milk (and its income), oxen for ploughing and for prestige (Karp, 1978).

3.2.4 Selection of the study area

Chakol Division was selected as the study area as a follow-up of the TSBF-CIAT research done under the Folk Ecology Initiative (FEI) that entailed participatory processes with smallholder farmers to share knowledge in soil fertility management. TSBF-CIAT has been very active in introducing and testing ISFM technologies since the late 1990s by establishing off-station soil fertility trials on farms with degraded soils. Through the FEI study, it was evident that the knowledge in soil fertility management held by smallholders in Chakol did not, as expected, translate into adaptive practices.

This study therefore aimed at understanding the reasons why this was so and the kind of soil fertility knowledge smallholder farmers in Chakol held and how it influenced the selection and application of soil fertility management technologies.

3.3 Research Methodology

This research was mainly exploratory. It entailed questionnaire surveys, focus group discussions and in depth interviews among key informants. This study sought to explore in as much detail as possible how farmers managed soil fertility, what soil fertility knowledge they possessed, how they acquired it and how they utilised this knowledge in soil fertility management. The reasons for use or non-use of different soil fertility technologies were also sought. A comparative approach of farmers participating in the FEI and non-FEI participant farmers was adopted in the analysis of their knowledge and management of soil fertility.

3.3.2 Study population and sampling design

a) Study population

The study population comprised all smallholder farmers in Akites and Aludeka sub-locations, Teso District, agricultural extension officers and researchers affiliated to TSBF-CIAT who had worked or were working in Chakol.

b) Sample size and sampling procedure

Identification of agricultural extension officers and participant and non-participant farmers was carried out with the help of the site Resource Farmer (RF) affiliated to the

FEI. The RF was knowledgeable in soil fertility management matters and knew the location and farming practices of most households in the area. He also kept records of participants in the FEI and had good rapport with local farmers.

A list of 184 smallholder farmers in Akites and Aludeka Sub-locations was supplied by the RF. Fifty farmers were then eliminated because they had participated in a recent similar study. From the remaining 134 farmers, simple random sampling technique was used to identify respondent farmers. Numbers corresponding with the names of smallholder farmers were written on small equal-sized pieces of paper which were folded into ‘balls’. These ‘balls’ were thoroughly mixed in two separate bowls; one for FEI participants and the other for non-FEI participants, before randomly picking 45 respondent farmers from each group. A sample size of 90 farmers for the questionnaire survey was finally arrived at with the unit of observation being the household.

For the focus group discussions, fifty most knowledgeable farmers were purposively selected from a list of farmers developed with the assistance of the RF. They were then individually approached and requested to participate in the exercise. Out of this, 36 farmers were available and willing to participate in the exercise; 18 FEI participant farmers and 18 non-FEI participant farmers and these formed the sample size for the discussions. Purposive sampling was also used in the selection of the key informants who consisted of three agricultural extension officers and two TSBF-CIAT researchers who had worked on soil fertility management related projects in Chakol.

3.2.3 Data collection methods and techniques

This study employed both qualitative and quantitative data collection methods. According to Mugenda and Mugenda (1999), qualitative research includes techniques, measures and designs that do not produce discreet numerical data. The tools adopted for obtaining data comprised the use of questionnaires for information from the smallholder farmers; checklists for participant focus group discussions and interview schedules for key informants.

The overall approach to the study was exploratory. For the ninety smallholder farmers, a standard questionnaire (Appendix A), was used to obtain information. Questions were both open-ended and close-ended. Since most of the questions were open-ended, in-depth interviewing was used to explore issues on soil fertility knowledge and management where themes were extracted from the questionnaires. Issues concerning these themes were then sought from the farmers and where necessary, subsequent visits were made having interview points of departure as any issues that required further clarification.

Focus group discussions involved thirty six farmers: 18 being FEI participants and 18 non-FEI participants. Each group was further divided into two sub-groups; nine women and nine men to ensure homogeneity and ease in management during the discussions. Each sub-group carried out separate focus group discussions (men only and women only) and later had a plenary session with the men and women together to discuss issues that required further clarification and debate. This grouping was done for both FEI and non-FEI participants and therefore in total, six focus group discussions were carried out; three with FEI participants and three with non-FEI participants.

Group discussions were steered by facilitators (the researcher and an assistant) who described the process and outlined the purpose of the exercise to the participants. A checklist (Appendix B) was used as a guide to obtain soil fertility information.

Key informants consisted of three accessible and willing agricultural extension officers and two researchers affiliated with TSBF-CIAT who had worked in Chakol in soil fertility management issues. The informants were approached for interviews, which were conducted with the use of interview schedules and notes taken. Even though several smallholder farmers were contacted and talked to informally, two individuals were purposively selected for in-depth case study analysis. Selection was based on their ability to utilise soil fertility knowledge and their knowledge sources.

3.2.4 Data analysis

Questionnaire data was checked and cleaned. Data from the open-ended questions were processed and coded to facilitate analysis. Statistical Package for Social Sciences (SPSS) was used for descriptive statistical analysis. The use of cross-tabulations and chi-square was also employed to show the relationships between the various variables. The findings were then summarised and presented as frequencies, percentages, tables and graphs.

Qualitative data collected from the focus group discussions and interviews with key informants was used to further explain the findings obtained from the questionnaires and therefore acted to supplement information obtained from the smallholder farmers. In addition, qualitative data from the case studies was presented verbatim.

3.4 Ethical Considerations

Subsequent to the selection of the respondents, consent to participate in the research study was requested. The purpose of the research study was explained to the respondents and confidentiality assured. Anonymity of their identities was assured through the use of pseudonyms and every effort was made to respect the wishes of the participating individuals.

CHAPTER FOUR

4. FINDINGS AND DISCUSSION

4.1 Introduction

This chapter presents and discusses the study findings on the level of uptake of soil fertility technologies and their sources. It also discusses the role of knowledge especially from the FEI on the selection and adaptive use of new soil fertility management technologies in the study area of Chakol. The findings are presented as frequencies and percentages, tables, charts and narratives.

4.2 Characteristics of the Study Sample

4.2.1 Age of the respondents

Seventy four (82.2%) of the 90 respondents were between 21 and 50 years of age. Out of this 74, 38 (51%) depended solely on agriculture as their source of livelihood while 34 (46%) supplemented agricultural income with off-farm earnings. This age range is usually the most economically active and it formed the majority of the respondents. According to Republic of Kenya, (2005), the labour force of Teso District was categorised as the age group between 15-64 years and this economically active group stood at 48% of the population in the year 1999. A positive environmental change can be achieved more effectively if this age range got more involved in soil fertility management initiatives.

4.2.2 Gender of the respondents

The sample consisted of 44 (48.9%) males and 46 (51.1%) females. This ratio may be attributed to the fact that according to the 1999 census, there were more female than male residents in Teso District. Besides, more women than men were involved in farming activities in Chakol and therefore there were more female farmers available for interviews. According to Republic of Kenya, (2005) in agriculture, women provide most of the labour and are also involved in income generating activities at community and household level and therefore contribute enormously to the economy of the District. However, according to the Iteso culture, the man is the head of the household and the one with full rights over land.

The sample of those who participated in the FEI consisted of 25 (55.6%) men and 20 (44.4%) women, whereas for non-participants, women were 26 (57.8%) and men were 19 (42.2%). There were more female non-participants than female FEI participants because farming activities which are mainly done by women are very involving which constrained women from participating in research events. This situation was further complicated by labour supply difficulties, demands by school-going children, household chores and limited capital to hire labour.

4.2.3 Education levels of the respondents

The majority of respondents 73 (81.1%) only had primary school education and/or informal education. Low levels of education partly explain why all the respondents either solely or largely depended on farming. Only few depended on more skilled forms of occupation such as teaching.

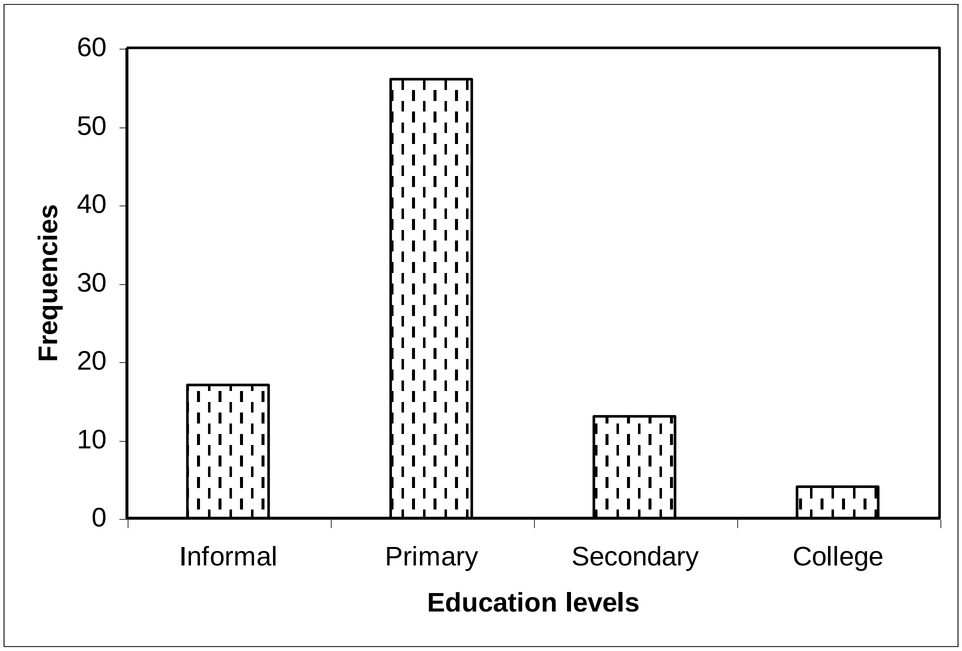


Figure 4.1: Education levels of respondents in Chakol

4.2.4 Land sizes of the respondents

During the study farmers were asked how much land they had and for those who had, for example 4.92 acres, the figure was rounded off to 5 acres during analysis. It was observed that, land sizes of the majority of respondents 66 (73.3%) were between 0.5 – 4.9 acres and only 5 (5.5%) had 10- 25.5 acres. The smallest land size was 0.75 while the largest was 22.5 acres.

Table 4.1 Land sizes of respondents within the study area

Land Size (acres)	Frequency	Percentage (%)
0.5 – 4.9	66	73.3
5 – 9.9	19	21.1
10 – 14.9	3	3.3
15 – 25.9	2	2.2
Total	90	100.0

Chakol had a population density of 427 persons per km^2 (Republic of Kenya, 2005). Although this density is relatively lower than other areas in western Kenya, the high fertility rate of 5.6 children per woman in Teso District (rated as one of the highest in Kenya the national figure being 4.7) (Republic of Kenya, 2005) and the consequent smaller land sizes complicate the long term meaningful soil fertility management.

4.2.5 Crops grown by respondents

The focus group discussions (FGDs) revealed that there has been a shift in the crops that are currently grown and those that used to be grown during the 1970s. In the 1970s and before, the Iteso mainly grew cotton, finger millet, sorghum, and cassava. Crops such as groundnut, bambara nut and green gram were grown in small amounts and were important for traditional child bearing ceremonies. Currently, crops largely grown in Chakol are maize (*Zea mays* L.), finger millet (*Eleusine coracana* (L.), sorghum (*Sorghum bicolour* (L.) Moench) with cassava (*Manihot esculenta* Crantz) and sweet potato (*Ipomoea batatas* (L.) grown widely as security crops that will withstand drought and feed families during famines. Legumes include common bean (*Phaseolus vulgaris* L.), groundnut (*Arachis hypogaea* L.), soyabean (*Glycine max* (L.) DC.), cowpea (*Vigna unguiculata* (L.) Walp.) and many species of vegetables.

In the early 1980s government-sponsored cooperatives that ran cotton ginneries in western Kenya failed to pay for cotton delivered by the local farmers and others, therefore causing a shift in the types of crops grown (World Culture Encyclopedia, 2008). As a consequence, with the aid of loans from large agricultural companies, Iteso farmers began experimenting growing new cash crops, such as tobacco (Ibid.).

4.2.6 Livestock reared by respondents

Poultry is the main livestock kept with few indigenous cattle, pigs, goats and sheep. The study findings indicated that cattle herds were not large with 59 (66%) households observed as having 1-5 cattle, 26 (29%) had no cattle at all while only 5 (5%) had 6-10 cattle. These low frequencies are attributed to the trypanasomiasis epidemic that occurred in the 1980s and wiped out most of their local herds. Reconstruction of the herds has been slow due to issues such as high poverty levels compounded by high cattle prices and reduced incomes and reducing grazing fields with the growing population. Flocks of free range poultry were however common among all the households interviewed with 86 (96%) households having 1-30 poultry.

4.2.7 Views of farmers on the status of their farm soils

The majority of interviewed farmers 57 (63%) indicated that the soil fertility status of their farms had shown improvement over the last five years while 33 (37%) indicated a decline in the soil fertility status of their farms. The differences in the proportion of people responding towards the change in soil fertility status was found to be statistically significant (χ^2 =69.5; df=40; p<0.003) at the 95% significance level.

4.2.8 Labour sources

The study revealed that 33 (37%) of the households interviewed in Akites and Aludeka had 6 or 7 children. We would expect large households to have more labour resources than smaller ones however; this may not always be the case. With the free education programme, more children were enrolled in schools and their contribution to farm work was reduced.

Traditionally the Iteso used to have *Ajono* (beer) parties, which entitled sharing of labour among neighbours, relatives and friends. These beer parties were very common after great harvests and participants in such a party worked on the host's farm and later shared *ajono*. Apart from labour sharing, these beer parties also served to bring people together in traditional ceremonies such as naming of the new-born, weddings and in conflict resolutions. With the decline in harvests and increased poverty levels, these beer parties and consequent traditional labour are barely being practised. In addition, the growth of Christianity, government policy against local brews and modern lifestyles have also interfered with these traditional labour sources.

Apart from the reliance on the little regular family labour (about 2 members i.e. the parents) that was available, the study showed that households turned to hired labour whenever they could afford, and from self help and church groups.

Table 4.2: Sources of farm labour for respondents within the study area

Labour sources	Frequency	Percentage (%)
Self (Respondent)	86	95.6
Family	74	82.2
Hired	61	67.8
Group Labour	48	53.2

4.3 Selection and Application of Soil Fertility Management Technologies

The soil fertility inputs that were investigated in this study were farm yard manure (FYM), compost and mineral fertilisers whereas for practices, cereal-legume rotation, burning, crop residue incorporation, biomass transfer, and natural and improved fallows were studied.

The findings as shown in Figure 4.2 revealed that the most common technologies applied by respondents were crop residue incorporation 76 (84%) and FYM 70 (78%) while the least applied were mineral fertiliser 6 (7%) and improved fallows 5 (6%). This reveals a general reliance on traditional, locally available resources compared to more modern technologies with the reasons cited as their availability and cheapness in terms of cost. These results further show that in addressing soil fertility management farmers first turn to resources that are available in their environment based on their local indigenous base before embarking on technologies from outside.

Dependence on more traditional technologies as shown in Figure 4.2 also reveals the reliance on local knowledge which is more familiar. Local knowledge according to Mango (2002) is that knowledge that is derived from the local peoples' past farming experience; from both the past and present generations.

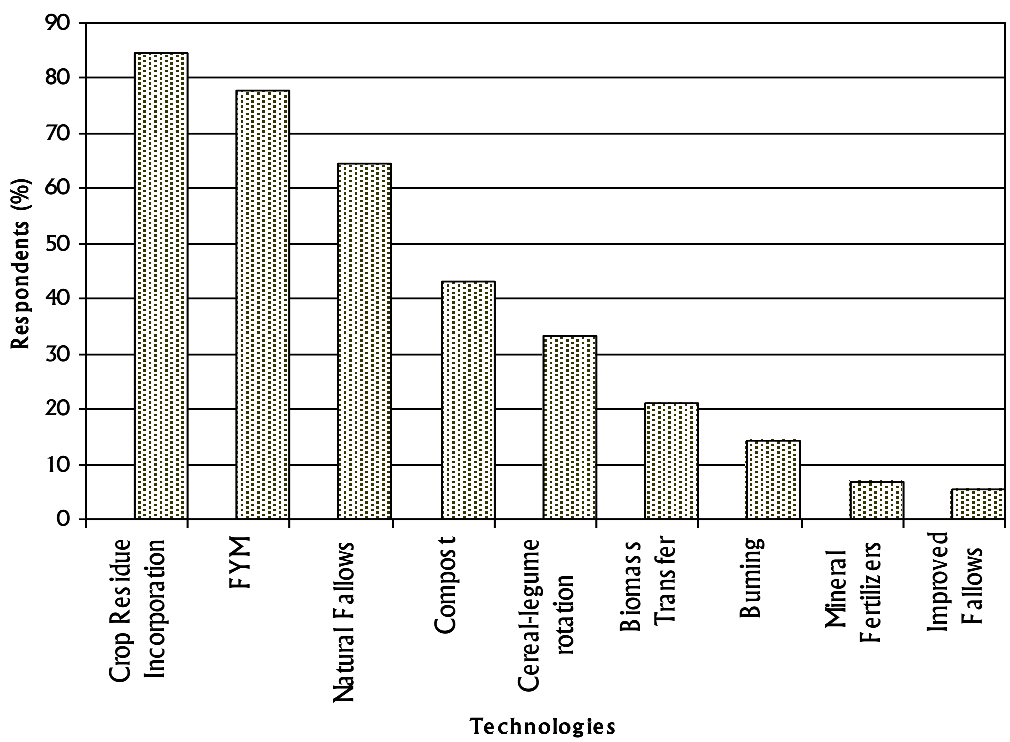


Figure 4.2: Application of soil fertility management technologies by respondents

Figure 4.2 also reveals that there has been a change in the soil fertility management practices and inputs that were applied in the 1970s and before and those used now. According to informants in the FGDs, farmers in the 70s mainly practiced shifting cultivation, natural fallowing and burning as a land clearance method. Currently, due to reduced land sizes and the consequent low soil fertility, a more intensive system of agriculture is imperative. Some traditional methods like shifting cultivation have been abandoned; others such as burning are being abandoned while technologies such as improved fallows and mineral fertilisers are being taken up.

4.3.1 Crop residue incorporation

Focus group discussions and individual farmer interviews revealed that crop residue incorporation on farm is a practice that has been carried out in the Iteso community over the years. Plant residues such as leaves and finger millet stover were left on farm and later incorporated into the soil before planting. However, stover of cotton, sorghum and maize which take longer to decompose were more often than not heaped together and then burnt.

Out of the 76 (84%) respondents that incorporated crop residue, 10 (13%) practiced it since this is what they had observed their parents do over the years. This shows that application of a technology went beyond awareness of its benefits and also depended on traditional familiarity, practicality and hands-on understanding. According to Yohannes and Galaty, (1993) this type of decision making that is outside the decision-maker's ordinary attention and awareness is called the unconscious processing and it is based on routine actions. Sixty six (87%) respondents however cited the importance of crop residue incorporation being to return nutrients to the farm from the decomposed matter and this was the reason why they carried out the practice.

In addition, this study revealed that for all the 76 respondents that incorporated crop residues on their farms, the main sources of crop residue for incorporation were legumes and stover of maize, sorghum and finger millet. Legume leaves were also burnt and the ash used in cooking local vegetables while stover was also used as fodder, mulch and fuel. These competing uses of crop residues left farmers with insufficient amounts for incorporation into the soil for soil fertility replenishment.

Maize and sorghum stover (*Akaserem)* decompose slowly and therefore acted as a source of disruption during tillage. Due to this, farmers opted to cut them into smaller pieces and leave them on farm or put them in a heap to decompose and later incorporate them into the soil during planting. Farmers were observed to innovate newer ways of handling stover.

For instance, Mr. Ekurutu, one of the smallholder farmers had found a way of 'boosting the quality' of his maize stover:

> "*I incorporate maize stover as a crop residue in my farm but they are low in nutrients and if the stalks are dry then they do not help. So for dry stover, I spread them on a section of my farm and put my cows there at night to sleep on them for about one month. The stover mixed with the manure when used during planting give better yield."*

4.3.2 Farm yard manure (FYM)

According to the findings of the study, a total of 70 (78%) respondents confirmed using FYM. Out of this, fifty three (76%), perceived it to be a cheap, readily available resource that reduced the cost of purchasing mineral fertilisers; 8 (11%) respondents used it to suppress *Emoto (Striga)*.

Striga hermonthica is a parasitic weed that attacks cereal crops by attaching itself to their roots and feeding on their nutrients causing crops to be stunted, discoloured and twisted AATF (2006). *Striga* has invaded an estimated 22 to 40 million hectares of African cropland, causing it to damage in excess of US$ 3 billion per year and is cited as a major cause of food insecurity and rural stagnation in Africa (Ibid.).

Plate 1: *Striga* invaded maize/cassava farm in Chakol, Teso District.

Plate 2: *Striga*-free maize farm in Chakol, Teso District.

The study findings revealed that more women 37 (53%) than men 33 (47%) utilised FYM either by incorporating it directly on farm or indirectly by adding it to compost. This can be attributed to the fact that poultry was the most common livestock in Chakol and poultry manure is mainly used by women especially in kitchen gardens. In addition, information from focus group discussions revealed that in the Iteso culture, small stock such as poultry and goats were owned by women and children whereas cattle, of higher economic value, were owned by men. Despite the fact that poultry was the most common livestock, cattle manure is more preferred in Chakol since it can be collected in larger quantities unlike that of chicken and goats that spend the day roaming and tethered in the compound respectively. But due to the small cattle herds [26 (29%) of the households having no cattle at all, 59 (66%) having 1-5 cattle and 5 (5%) having 6-10 cattle] 19 (21%) out of 70 farmers who applied FYM saw it fit to put their little available manure in the compost rather than use it directly on their farms. This was seen as a desperate effort by resource-poor farmers to meet subsistent needs by making use of all the available resources and that it covers a wider area rather than as a strategy for better nutrient-use efficiency for soil fertility improvement.

It is important to note that, the mere use of FYM does not guarantee a farmer of increased harvests, the method of preparation, storage and use influences the quality. This was clearly revealed in the study where 9 (12%) of the respondents who used FYM reported not having achieved any increase in their yield. Further probing revealed that, respondents had the information that it was important not to expose the manure to direct sun and rain because of nutrient loss through volatilisation and leaching respectively. However due to the convenience of just heaping the manure next to the animal shed they did not put this knowledge into action.

As stated by Mr. Okitwii:

> "*We have been taught in our farmers' group that FYM loses vital minerals if left exposed to direct sunlight and rain and I suppose this is the reason why I did not see an increase in yield despite having used it."*

This clearly shows that despite the knowledge held, expediency, in terms of labour and time plays a vital role in determining how a technology is applied.

4.3.3 Natural fallows

Natural fallows were practiced by 58 (64%) of the respondents with 32 (36%) stating that they were not employing the practice due to limited land.

During the FGDs, farmers indicated that natural fallows were common in the 1980s and before due to low population. They further stated that, although natural fallows are still practiced, fallow fields have decreased in acreage and fallow period (averaging 6 months). In addition, were it not for lack of labour to cultivate all the land one has at a go, the need for grazing land, lack of capital and incidences of flooding during the long rains, natural fallows would hardly be practiced anymore. This was confirmed by all the 58 respondents that practiced natural fallowing. Mango (2002), observed that, the presence of natural fallows can be a sign of distress rather than positive management and is largely due to the household lacking sufficient labour, money or animal traction to cultivate their fields.

4.3.4 Compost

Resources were available that could be used to make compost and reduce the need for mineral fertiliser among farmers. The cost of fertiliser was the reason cited for compost use by 39 (43%) of the respondents. Thirty seven (41%) said they knew how to prepare it and had knowledge of its benefits in increasing yields, however due to the labour needed in digging the pit and turning the compost to ensure even decomposition, they did not make it. This was also confirmed by female headed households where male members were absent.

According to Mama Rosa, a widow:

> *"Since my husband is deceased and the children are very young, digging the compost pit is difficult work for me and therefore I do not prepare compost manure."*

Compost is therefore not accessible to labour deprived farmers. It is labour intensive and requires a certain level of knowledge to meaningfully apply. Its availability is therefore not an immediate advantage in Chakol.

4.3.5 Cereal-legume crop rotation

This study shows that 30 (33%) households planted legumes (groundnut, soyabean and common bean) and cereal (maize) on a rotational basis because this helped to avoid depletion of particular nutrients by breaking the mono-cropping cycle. Legumes aid in adding nitrogen and carbon to the soil.

Sixty respondents (67%) did not follow a cereal-legume rotational sequence. Out of this, 25 (47%) respondents stated that although they knew the importance of rotating cereals and legumes on their farms, they were unable to carry out the practice due to small land sizes. It was however not clear whether an increase in land would lead to better adoption of legume-cereal rotation or basically in the extension of the acreage of more preferred crops.

Due to local contextual judgement and conditions such as small land sizes, risk aversion like rain patterns and *Striga* control, farmers were observed to come up with their own versions of crop rotation schemes. Although FEI demonstrated cereal-legume rotation, re-designing of the concepts taught was observed. Because of small land sizes, for 25 (47%) of the respondents, the preference of cassava that took longer to mature, and *Striga* invaded fields, crop rotation was usually substituted with intercropping. This mainly aimed to ensure food security by maximising the benefits from the little land available, through for example, management of risk, reliance of N_2-fixation, reduction of tillage requirements.

It was observed that despite the introduction and dissemination of knowledge on new cereal-legume rotation schemes, farmers still practiced traditional rotation systems e.g. maize and cassava alternation. Although cassava is not a legume, subsequent maize performances were said to be better. There is the thought by farmers in Chakol that maize draws nutrients at a shallower depth than cassava that has deeper roots and it therefore 'pulls' nutrients to the surface that the ensuing maize utilises. According to Misiko (2007), farmers also reported this belief from West Africa and it may have some basis that is not yet fully understood (cf. Saidou, 2006).

4.3.6 Biomass transfer

Biomass transfer refers to the mulching or green-leaf manure using foliage of trees and shrubs cut and carried to cropping areas (ICRAF, 2006).

Nineteen (21%) respondents cited using *Tithonia diversifolia* and *Calliandra calothyrsus* as biomass in their soils. Respondent farmers in Chakol perceived legume crop residues and *Tithonia* to be the best sources of green manure since they decompose fast. High quality organic inputs decompose relatively fast, and are therefore able to release nutrients that can be utilised by growing plants in the short term (Mapfumo et al., 2001). Farmers in Chakol usually cut the leaves of *Tithonia* and spread them on the farm or chop them into small pieces and place them in planting holes for about a week to decompose then incorporate into the soil before planting. Although *Tithonia* decomposes fast, farmers described it as inconveniencing in terms of labour needed to cut and carry it therefore its use was limited to small plots especially of vegetables such as kale and usually on an experimental basis.

Calliandra was introduced in Chakol by the Kenya Wood-fuel and Agroforestry Project (KWAP). It was mainly promoted for its benefits as wood-fuel, fodder and for erosion control. Its usefulness in soil fertility replenishment started to be popularised by TSBF and its partners from 2001. Unlike *Tithonia*, *Calliandra* takes about three weeks to decompose, is more difficult to cut and it does not grow wildly in Chakol.

Tithonia preference, 14 (16%), was therefore higher among farmers in Chakol compared to *Calliandra* that was only used by 5 (6%) although labour demands was cited as the major limiting factor to the use of both *Calliandra* and *Tithonia* in biomass transfer.

4.3.7 Burning

Despite farmers' knowledge of burning on farms especially of crop residues and weeds as an unsustainable method in soil fertility management 6 (7%) still carried out the practice on their farms to save on labour and as a method of quick land clearance whenever they were late for planting. Two (2%) female respondents were instructed by their husbands to carry out burning while 5 (6%) respondents reported having tried burning and after attaining increased yield, they continued practicing it.

However 77 (86%) stated that burning has been on the decline for the last 25 years in Chakol. Various institutions such as the Kenya Agricultural Research Institute (KARI), Ministry of Agriculture (MoA) in Kenya, schools and other institutions have educated farmers on the advantages and disadvantages of burning such as loss of nutrients and killing of micro-organisms and many farmers have since stopped burning. Farmers have experimented and learnt through experience that they obtained increased yields during the initial seasons following burning but a decrease in yields in subsequent seasons and this proved that burning is unsustainable for soil fertility replenishment.

FGDs revealed that in addition to acquiring knowledge on the drawbacks of burning, the main reason for the decline in slash and burn was the decrease in bushes and thickets. With the increase in population, bushes and thickets have been replaced by cultivated fields and therefore not much is left for burning. Besides, there is a marked drop in crop yield and therefore less stover to handle on farms. There is less and less fallowing over time and therefore less need for burning on farms. In addition, firewood requirements have increased, yet there are fewer trees to spare and so every available resource is reserved for fuel wood.

4.3.8 Mineral fertiliser

Mineral fertiliser was among the least applied technologies in soil fertility improvement in Chakol. Even 6 (7%) of the farmers who used it stated that mineral fertilisers were expensive hence mainly used on selected crops that are considered to give high returns which they can then plough into other ventures. These crops include maize, soyabean and vegetables such as kale and tomatoes grown for sale. Farming is the main source of livelihood in Chakol and most crops grown were for subsistence use. The low application rate of mineral fertiliser was because of capital constraints.

As stated by Mr. Wekesa, a researcher

> "*Farmers in Chakol have the will to incorporate both organic and mineral fertilisers in their cropping systems, however they lack the capacity to buy the mineral fertilisers.*"

According to a front line extension officer working in the Ministry of Agriculture, farmers in Chakol had for long held the belief that mineral fertilisers 'spoilt' their soils. This according to the officer meant that soils became acidic. This perception that mineral fertilisers are harmful is what the ministry has been trying to change through field demonstrations. With time, farmers have been slowly changing their discernment of mineral fertiliser, however this has not translated to an increase in its use and the major constraint was observed to be lack of finances by farmers; a sign of poverty.

4.3.9 Improved fallows

This refers to the growing of selected species of leguminous trees, shrubs and herbs that perform better than indigenous fallow species for their soil enrichment capacity or useful products.

In Chakol *Mucuna pruriens* (velvet bean) was promoted for rotation and as a fallow crop by FEI. Mr. Wafula a researcher with the FEI stated that "promotion of *Mucuna* by FEI was not emphasised on. This is because farmers rejected it due to its low edibility." The findings of this study concurred with the above statement and it revealed that none of the respondents in Chakol planted *Mucuna* on their farms. For *Calliandra*, 5 (6%) farmers cited growing them as a source of fodder, for fencing and to obtain seeds for sale with its purpose in soil fertility replenishment mentioned as the least priority. For 34 (48%) who knew about improved fallows but did not practice them, land was stated as the main constraint and therefore precedence was given to edible crops. Because of limited available resources, farmers made decisions based on the tangible benefits that they expected to get such as food and income with their main priority being food security.

4.4 Soil fertility indicators employed in the study Area

During the FGDs farmers stated that they relied on various indicators to determine whether soil was fertile (*Abosetait)* or infertile (*Atoot)*. These indicators played a great role in the determination of the soil fertility status of soils by most farmers and consequently influenced their choice of soil fertility management; whether to use organic or mineral fertiliser or a soil fertility management practice.

In Chakol, the number of cobs on a maize plant or the yield e.g. the number of bags harvested was the most commonly used indicator of soil fertility. In Chakol, high yielding soils were considered more fertile than the less yielding ones. Crop characteristics such as dark green colour of leaves, thickness of stems and fast growing crops were also used as indicators of fertile soils. According to Mango, (2002), farmers mainly assess yield in terms of crop performance which in turn indicates which parts of the plot are experiencing fertility decline. Among FE participants, purple colour on the margins of leaves was cited as an indicator of low phosphorus levels while the yellowing of leaves from the mid-rib was cited as an indicator of low nitrogen levels. This was after their taking part in FEI participatory soil fertility deficiency test strips planted in representative local soils. In cases where phosphorus deficiencies were determined, mineral fertiliser would be preferred and as for nitrogen deficiencies, other alternatives would be the use of farm yard manure (FYM) or cereal-legume rotations.

Other indicators of soil fertility included different grasses and weeds (*Inyaa*) that had been traditionally known to grow in either fertile or infertile soils. Some of the most common grasses that were used as indicators of soil fertility include *Cynadon dactylon* (*Emuria)*, *Digitaria Scalanum (Ekonet,)* and *Panicum maximum* (*Eturai)*, while *Harpachne schimperi* (*Epero), Conynza banariensis* (*Emelait)* and *Striga hermonthica* (*Emoto)* are grasses and weeds that were highly associated with infertile soils.

Farmers' knowledge on the different soil types and their characteristics was observed to be extensive. Different soil types had specific names in the local dialect. Black cotton soil (*Amoni)* was considered the most fertile and best for agriculture followed by swampy soils (*Akapian)* that were found in the lower swampy areas.

Soil texture, colour and sometimes smell were used as indicators of soil fertility (*Abosetait).* Individual farmer responses and focus group discussions revealed fertile soils as those that are partially sticky, forms lumps that easily crumble and are black in colour. It was further stated that with continuous cultivation, soils could change from one appearance to another. Soils that were considered most fertile, *Amoni*, could change from their black colour to a lighter hue which was an indicator of loss of *abosetait*. Farmers cited these soils as those that were largely found in the middle parts of their fields. Sandy gravel (*Alupo Nukang'aroi),* sandy soil (*Asinge)* and white clay soil *(Edoto)* were, according to the farmers, the least fertile soils and therefore least suitable for agriculture.

It was observed that this knowledge on soil fertility and which farm sections were more fertile had an influence on the selection of crops to be planted on which farm parts and the soil fertility management strategy employed.

Table 4.3: Soil fertility replenishment technologies and the fields they are employed

Soil fertility technology	**Home fields (*Ariri)***	**Outfields (*Oshali)***
Farmyard manure (FYM)	32	24
Compost	8	26
Legume rotation	0	24
Crop residue incorporation	8	33
Natural fallows	10	35

Table 4.3 above reveals that respondents preferred employing soil fertility management technologies in the sections of their farms away from their homestead-outfields (*Oshali*), with the least preferred being the sections close to the homestead-home fields (*Ariri*). This was observed in all cases except FYM whose main source was poultry and therefore mostly used in the kitchen gardens.

The home fields include kitchen gardens and were ranked by the farmers as more fertile than those sections further away. These nearby farm sections tend to receive regular amounts of chicken manure and organic wastes such as kitchen refuse and crop residues due to their proximity to the homestead. Labour intensive soil fertility practices such as biomass transfer using *Tithonia* was also cited as being applied in kitchen gardens.

Tithonia is a plant that over the years has been growing wildly in western Kenya. In Chakol, *Tithonia* has been perceived as a weed, fodder for goats, medicinal plant, hedge plant and as fuel for tobacco curing. Fourteen informants, who applied *Tithonia* for soil fertility replenishment in biomass transfer, stated that they felt inconvenienced by its labour intensiveness and therefore used it on kitchen gardens and mainly on a trial basis. In addition, its uptake in soil fertility replenishment had been prevented due to its reduced availability. With *Tithonia* increased usage by farmers in tobacco curing and its importance in soil fertility improvement becoming more known, there was an emergence of restriction of its plucking by farmers.

As Mr. Ochudi stated:

> *"We are now aware of the benefits of Tithonia but it is very labour intensive. Nowadays, it is even less available than before because of its use in curing tobacco and restriction to pluck it by those farmers who have it growing near their farms."*

Thirty two respondents said they applied FYM on the home fields. Their reasons for this preference was largely due to the fact that the FYM that they had was usually in small amounts, since 85 (94%) of the households reared mainly poultry and goats with only 0-5 cattle. Households with more than 5 heads of cattle would give some of their livestock to their relatives or friends who had larger grazing fields to rear them on their behalf. This practice in Ateso community is known as *Ekipukone.* The new caretakers are entitled to the ownership of every second born calf and the benefits from all the livestock such as milk and manure, but not ownership of the initial livestock. However the Iteso hold cattle in high regard and are used as bride wealth, for ploughing, for sale and prestige.

The outfields which constitute a larger proportion of the total acreage were cited by farmers as the ones where continuous cultivation has been carried out over the years, with little soil fertility replenishment. These fields have therefore lost most of their productivity and hence an indicator of reduced soil fertility. As a result, most soil fertility management practices were observed to be employed in these fields by respondent farmers.

However for those farms located near the Kenya-Uganda border in Aludeka sub-location, their soils were majorly alluvial (*Akapian)* in nature and these soils are suitable for rice cultivation. These farms are generally considered very fertile because continuous cultivation does not take place here due to the seasonal flooding which forces the community to leave these fields as natural fallows during these times.

4.5 Networks and Linkages

According to Mango (2002), networks are made up of sets of direct and indirect relationships and exchanges (interpersonal, inter-organisational and socio-technical). Farmers in Chakol received knowledge on better soil management technologies such as soil erosion control using terraces, retention ditches, contours and gabions. In addition, agroforestry practices, crop rotation, better use of locally available manures and mineral fertilisers were taught. Institutions that were involved included the World Agroforestry Centre (ICRAF), the Kenya Agricultural Research Institute (KARI), the Kenya Wood-fuel and Agroforestry Project (KWAP) and the Tropical Soil Biology and Fertility Institute (TSBF). Apart from these research institutions, the findings of this study revealed that farmers also acquired knowledge on better soil and farm management from the Ministry of Agriculture (MoA) extension officers, their neighbours, inherited knowledge from the older generations, local groups and through observation and experimentation.

Table 4.4: Knowledge sources and their frequency of application by farmers in Chakol

Knowledge sources	Responses on knowledge acquisition	Knowledge Application	
		Frequency	Percent (%)
Researchers	70	47	67
Extension officers from MoA	22	6	27
Neighbours	23	14	61
Others (older generations, local groups, observation & experimentation)	59	42	71

Out of the 59 respondents that acquired better soil management knowledge from the older generation, local groups, observation and experimentation, 42 (71%) applied that knowledge on their farms. This shows that there is a more reliance on local knowledge since it is more practical and familiar. In addition, of the 70 respondents that cited having received soil fertility knowledge from researchers, 47 (67%) stated having applied it. The high frequencies in application of knowledge acquired from researchers and ‘others’ can be attributed to the use of participatory and demonstrative methods of knowledge dissemination, rather than the mere use of theory. Mango (2002) stated that farmers learn more by doing, they observe and evaluate the course of events on their farms and those of others and use this to change the existing practices if deemed necessary. Research institutions and projects that have worked in Chakol such as TSBF-

CIAT and KWAP used participatory demonstration approaches where the farmers were involved in the implementation of the project and this created a feeling of ownership and sustainability of the project work.

From the study, the least applied knowledge was from extension officers from the MoA. According to Mr. Barasa, a frontline extension officer with the MoA, the ministry has demonstrated on soil erosion control measures and on the use of mineral fertiliser in Chakol. Information on other soil fertility technologies such as crop rotation, intercropping and use of locally available organic manures has also been disseminated with little demonstration done. Due to being under-staffed, the Ministry of Agriculture (MoA), in Chakol, uses a demand-driven approach where the farmers approach the extension officers whenever they have a problem on their farms and the extension officers then visits those farms. This demand-driven approach however may not be the most suitable to farmers unless they are proactive. Extensive application of the knowledge disseminated by the ministry was hampered by the lack of finances to purchase mineral fertiliser by the farmers and the lack of labour to implement soil erosion measures such as terraces, gabions and retention ditches. The ministry has therefore started using the group approach system for extension, where group members act as a source of labour in putting in place some of the soil control measures for one of their own. It has also been advocating for less labour intensive measures such as contouring.

Networks play a great role in re-designing technological innovation, which consequently gives rise to variable patterns of agricultural development. For instance in Chakol, *Tithonia* has been growing wildly, but various knowledge networks have changed the views of farmers about it from just a mere shrub to its current usefulness in biomass transfer as promoted by the FEI. Other uses are its concoction as a pesticide and fertiliser as adapted by farmers and for tobacco curing as promoted by Mastermind Tobacco (K) Ltd.

Knowledge networks in Chakol were observed to play a role in the application or de-linking by farmers from a soil management technology. For example, this study revealed that 68 respondents no longer used burning as a land clearance method or burnt crop residues following the advice by a neighbour, friend or one of the research institutions that burning is an unsustainable soil fertility management practice. Because some farmers carried out burning on an experimental basis on small sections of their farms to verify the advice given, it was common for the researcher to observe the lack of uniformity in growth of crops that had been planted at the same time due to these burnt patches.

The foregoing findings show that knowledge networks were helpful to smallholder farmers in making informed decisions about soil fertility management and are hence avenues for technological change and innovation. Therefore depending on their impact in the community, they can be exploited in the dissemination of better farm management knowledge.

4.5.1 Case studies of knowledge sources and application

The case studies below show the role that linkages can play in the dissemination of soil fertility knowledge and its application. That one does not have to have a direct link with the original source of knowledge but through forming associations, knowledge disseminated to one group of people can reach many others. For proper decision making, knowledge is required and one way to acquire knowledge is through networking and forming linkages with institutions, individuals or groups.

Box 1: Case study of Mrs. Ochoo (successful farmer)

Mrs. Ochoo was one successful farmer that was observed. Her accomplishments were attributed to her hard work, experimentation, observation and advice from neighbours. At the age of fifty, she and her two daughters were the sources of farm labour in their 7 acre farm while her husband attended to their small business. Despite having not attended formal schooling her practical knowledge was well utilised. She was a non-FEI participant but she actively sought information from neighbours, friends and relatives. Her little available FYM was added to a covered compost pit; she carried out cereal-legume rotation and practiced natural fallows. She also incorporated crop residues and used *Tithonia* and *Calliandra* in biomass transfer. *Calliandra* was also planted to control soil erosion on her farm.

Box 1: above, the case of the successful farmer highlights a farmer who does not associate with researchers but utilises the technologies that the researchers promote.

Despite the fact that Mrs. Ochoo was a non-FEI participant, some of the technologies and methodologies that she applied such as sheltering her manure from heat and rain, which result in volatilisation and leaching respectively, cereal-legume rotation and the use of *Tithonia* and *Calliandra* in biomass transfer were all technologies promoted by the Folk Ecology Initiative (FEI). This was made possible by forming linkages with relatives, friends and neighbours who acted as media of knowledge transfer. Here the fact that knowledge is not static is also revealed where knowledge from FEI is transferred from participant farmers to non-FEI participants.

This case study also reveals the influence of practical knowledge; that one need not have acquired formal education to properly manage their farms, Mrs. Ochoo's open attitude to actively seek soil fertility information by linking with friends and relatives, make observations, readiness to carry out experiments and efficiently utilise the available resources led to her success.

Box 2 Case study of Mr. Ayege (a not so successful farmer)

Mr. Ayege was a farm labourer in a soil fertility demonstration site that was located next to his two acre farm. Despite soil erosion having taken place on his farm, no erosion control measures had been put in place. He utilised FYM from his two cattle but this was hardly enough for his whole farm. He carried out crop rotation but with no sequence followed and also incorporated crop residue on farm. No other soil fertility replenishment strategy was employed and therefore his yield had been dwindling over the years. Mr. Ayege was also not involved in any farmers' group or in the FEI. He also did not attend any seminars. To him these were a waste of time and he preferred getting something tangible such as mineral fertilisers rather than 'sitting and talking'.

Box 2 reveals a farmer who is involved in soil fertility management activities with researchers and lives near a demonstration site but does not take up the technologies that are promoted.

This farmer distanced himself from any associations with farmers' groups and consultation with neighbours. On probing him as to why he did not take up the technology that was being applied next to his farm and which seemed to be having a positive impact, Mr Ayege stated that he just did his job and did not enquire on the importance of the technology. He went on to add that crop yields from his farm had been dwindling and he wanted a quick-fix solution such as fertilisers rather than time consuming solutions such as biomass transfer using *Tithonia.*

4.6 An assessment of the influence of the Folk Ecology Initiative (FEI)

The Folk Ecology Initiative (FEI), a TSBF-CIAT approach that was launched in 2001, aimed at building a strong and dynamic knowledge base for solving soil related problems through interactive learning rather than handing over ready to use technologies. It was also aimed at enabling better understanding into rural problems and coming up with solutions that draw on rural skills using smallholders and through resource farmers (RF) for sustainable relationships (Misiko, 2007).

FEI was implemented in six sites in western Kenya between 2001 and 2008, Chakol in Teso District being one of sites. It employed participatory experimentation, monitoring and evaluation (PM&E) over the following trials on soil fertility management:

1. Cereal legume rotations using *Mucuna*, soyabean, yellow gram and groundnut.
2. Organic resource quality (ORQ) concept implemented through the practice of biomass transfer using locally available resources for soil amendments such as FYM, *Tithonia* and *Calliandra.*
3. Mineral fertiliser responses with a focus on nitrogen (N) and phosphate (P) fertilisers.
4. FYM response with special emphasis on quality management.
5. Multipurpose grain legume screening, especially targeting new soyabean and groundnut varieties.
6. Soil nutrient test-strips aimed to illustrate typical symptoms of nitrogen (N), phosphorus (P) and potassium (K) nutrient deficiencies.

In a nutshell, FEI was based on the assumption that people will take ownership of the research process if they are central in the design and implementation of programmes that affect their livelihoods and if they make personal commitment to them (Scoones et al., 1994)

Table 4.5: FEI Participation and application by respondents of the knowledge it disseminated

Respondent type	Whether applied FEI knowledge					
	YES		NO		Had no FEI knowledge	
	Count	Percent	Count	Percent	Count	Percent
FEI participants	45	100	0	0	0	0
Non-FEI participants	19	42.2	7	15.6	19	42.2
TOTAL	64	71.1	7	7.8	19	21.1

The study findings revealed that FEI knowledge was applied by all 45 (100%) FEI participants and almost half 19 (42%) of the non-participants. There was also a significant relationship between participation in the FEI and application of its knowledge (χ^2 =69.5; df=40; p<0.003) at the 95% significance level. This clearly shows that FEI had a positive impact in the management of soil fertility in Chakol and in assisting farmers make informed decisions.

In addition, since this study revealed that a significant number of non-participants (42%) applied FEI knowledge, this implies that knowledge is not static. FEI participatory meetings and demonstrations in Chakol were open to all farmers whether participants or not. In addition, neighbours, local groups and friends, acted as modes of knowledge spread. As observed by Reijntjes et al., (1992), ‘knowledge if locally beneficial spreads by word of mouth, imitation or informal education in village meetings, etc.’

Whether a farmer had acquired formal or informal education was not a determinant of their participation in the FEI. At the 95% significance level, no relationship was revealed between education levels of the smallholder Chakol farmers and participation in the FEI (χ^2 =2.29; df=3; p<0.514). The FEI used participatory demonstrations with less technical language and translation into the local dialect wherever possible in the dissemination of knowledge on its technologies. This approach if adopted by research institutions and organisations is likely to have a positive impact in reaching a wider scope of community members whether they are formally or informally educated.

Thirty farmers (33%) cited practicing cereal-legume rotation. Out of this no respondent cited utilising *Mucuna* as a rotation legume while 16 (53%) used soyabean, groundnut or common bean in their rotation practice. With the ever increasing population and pressure on land cereal-legume rotation is not a sustainable practice in Chakol. However, despite the low uptake of cereal-legume rotation, FEI had an appreciable positive impact in the uptake of soyabean by smallholder farmers in Chakol. This study revealed that 54 (60%) farmers took up the growing of soyabean which was popularised by FEI. Soyabean is a legume crop that has multiple potential uses e.g. for food, nitrogen fixation, income and biomass incorporation.

FEI disseminated knowledge on organic resource quality concepts and biomass transfer in Chakol.

In FYM use, FEI was observed to have a considerable positive impact. Despite the fact that cattle manure in Chakol is more preferred than poultry or goat manure and 94% of the households interviewed had 5 cattle or less, the little manure available was utilised either directly or in compost by 70 (78%) of the respondents while 12% of the respondents attributed their lack of increased harvests to the poor quality manure that they used. This study further revealed that FYM was not only used for the sole purpose of increasing yield but also for suppressing *Striga* weed. In addition, 76% cited using it due to its cheapness and availability and therefore a good alternative to mineral fertiliser which is costly. This clearly shows that FEI had a noteworthy positive feedback towards the utilisation of FYM not just as a locally available resource but also in influencing that better quality manure was used for maximum benefits.

The use of *Tithonia* and *Calliandra* however was only employed by 19 respondents with limited land and labour being cited as the major constraints. As much as these are very viable resources for soil amendment they are not an immediate solution for Chakol soils unless land and labour issues are addressed first.

Mineral fertiliser was used by only 6 (7%) of the respondents with 84 (93%) citing not using it. Mr. Wafula, a research assistant stated that nitrogen and phosphorus are the most limiting nutrients in Chakol soils. Therefore, mineral fertiliser and especially phosphatic fertiliser are essential to replenish these soils. Nandwa (2003) stated that nitrogen replenishment strategies have good biological sources such as FYM, nitrogen fixation via legumes and biomass transfer of organic resources such as *Tithonia* and *Calliandra,* but this is not the case for phosphorus replenishment strategies which tend to be mainly mineral fertiliser-based.

Farmers in Chakol cited having knowledge of fertiliser which are also available in the area with their expensive nature acting as the major hindrance to their use. The way forward to solving this would be to look into ways that smallholder livelihoods in Chakol can be improved so that farmers can then afford these fertilisers. FEI therefore did not have an impact in the application of mineral fertilisers by farmers due to their high costs although it had an impact in the dissemination of knowledge on its importance and better use among farmers.

4.7 Summary

The findings of the study have been presented in accordance with the four study objectives

The first objective aimed to establish the role of knowledge on the selection of soil fertility technologies among smallholder farmers while the second objective investigated the role of soil fertility knowledge on the nature of application of soil fertility management technologies

The data from the survey revealed that farmers had the knowledge on the preparation, benefits or drawbacks of soil fertility inputs and practices but the decisions they made towards their selection and application were affected by poverty indicated by factors such as labour, capital and land constraints. It is clear that farmers preferred inputs that were practical in terms of time, complexity and labour demands such as crop residue incorporation and farm yard manure, in addition, those that had higher returns and preferably with multiple benefits such as cereal-legume crop rotation. Soil fertility management technologies that were less accessible such as mineral fertilisers, no matter how effective and labour saving, were least considered and or taken up.

A high dependence on local knowledge was revealed in the greater reliance on more traditional soil fertility management technologies such as natural fallows, farm yard manure and natural fallow. This was attributed to the fact that these technologies were more familiar and practical to respondents as opposed to more modern technologies such as improved fallows and fertilisers.

Farmers were observed to use various plant and soil indicators in determining whether soil on their farms was fertile or infertile. These indicators included crop yields, crop characteristics (such as colour of leaves, thickness of stems and rate of plant growth), types of grasses and weeds, soil texture, colour and sometimes soil odour. These indicators influenced the type of crop to be grown and on which section of the farm and the best soil fertility strategy to be employed.

The third objective evaluated the importance of different knowledge networks in the selection and implementation of soil fertility management practices. Knowledge networks were observed to form avenues of soil fertility management information dissemination. Knowledge networks offered a ‘basket of options’ to farmers and therefore influenced better decision making. As a result, farmers applied the knowledge as taught, re-designed it to suit their individual circumstances or de-linked themselves from the knowledge network or technology.

High frequencies observed in the application of knowledge from the older generations, local groups and from observation and experimentation indicated the reliance on local knowledge that was more practical and that farmers learn more by doing and through observation.

The last objective explored the influence of the Folk Ecology Initiative (FEI) on soil fertility management in Chakol. The impact of FEI was significant in better FYM utilisation and in soyabean uptake as a legume crop. FEI also had a positive impact in the dissemination of knowledge on the proper use of resources such as of mineral fertiliser, cereal-legume rotation and biomass transfer of *Tithonia* and *Calliandra* although their extensive uptake was hindered by limited capital and labour constraints.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter ties conclusions with the literature review and study findings. This study was carried out with the objective of investigating the relationship between soil fertility management knowledge and the selection and effective use of the various technologies in the improvement of soil fertility of the degraded soils of Chakol. It also aimed at examining the influence of various knowledge networks and of the FEI in the management of soil fertility in the area. Consequently, the study aimed at suggesting possible solutions to the constraints of these objectives. Conclusions arrived at and recommendations made thereof are summarised in this chapter. In addition, this chapter gives recommendations based on the research findings for better soil fertility management. Finally it proposes areas for further research in the study area.

5.2 Conclusions

From the study findings we can conclude that there is a strong link between knowledge and practice in soil fertility management among smallholder farmers of Chakol. Knowledge offers farmers different alternatives to choose from when deciding on the most suitable soil fertility management strategy to employ. As a result, the decisions that are arrived at are more informed and objective. Without the foundation of some fundamental knowledge, then hardly would any soil fertility management technology be employed.

In Chakol the extensive utilisation of the knowledge held by respondents was observed, in all technologies, to be constrained by different local contextual factors such as labour, capital and land. Therefore from the study, it was evidenced that knowledge was not the main determinant in the selection and application of the various technologies by Chakol farmers and in all technologies studied, poverty often overrode selection and application no matter how viable and profitable a technology was. In order to provide viable solutions for Chakol smallholder farmers recommendations made must target to eradicate poverty which was the main hindrance to the utilisation of the soil fertility management knowledge that the farmers held.

One of the recommendations that is imperative in order to guarantee the sustainability of any technology introduced in a local community, is the future projection of the local and demographic dynamics such as population increase on land sizes. In Chakol, the technology introduced should aim to transform an extensive management system into an intensive one which involves changes in extension strategies and resource utilisation. In this circumstance, with the increasing population, cereal and legume intercropping for Chakol farmers seems a more viable technology for the present and future than the cereal-legume rotation that was promoted by FEI.

In the case of mineral fertilisers, since capital was the main constraint, the promotion of N-fixing legumes such as soyabean and cowpea provide a good starting point. Such legumes provide benefits to farmers in terms of enriching the diet, provision of high quality fodder, as an income source and direct N-addition to soils. Better incomes would mean more money to purchase mineral fertilisers - spill-over effect of one solution for another. Opportunities that link farmers with markets also need to be created. This will allow them invest in external inputs for their farms. By farmers combining their little harvests to form bulk and creating marketing groups, they will gain bargaining power to avoid being exploited by brokers especially those that buy maize from individual farms. Formation of marketing groups will also enable them enjoy economies of scale such as reduced transport costs to markets which are located about 15kms to either Busia or Malaba. The government should also step in and improve infrastructure. The poor road that links Chakol to the better markets in Busia and Malaba requires proper construction so as to reduce the cost of transport of farmers' produce to markets.

Since Chakol soils are of a sandy nature, efficient use of nutrients should involve the frequent and timely supply in quantities sufficient to meet crop needs. This includes the application of mineral fertilisers in multiple split doses which also saves on labour which is limited in Chakol.

In Chakol, the study revealed that the knowledge networks that had the greatest impact in the dissemination and consequent application of soil fertility knowledge were researchers, local groups and farmers' observation and experimentation. These knowledge avenues should be targeted and the methodologies that make them more effective such as the use of participatory methods, taken up by other projects and institutions to enhance soil fertility knowledge spread and application. On-farm demonstration sites should also be located in strategic places such as near major roads or near a market place so as to target a larger population not necessarily to offer a solution to a problem but also to serve as a basis for better farmer decision making.

5.3 Suggestions for Further Research

From the conclusion, we can make the recommendation that further research should be conducted on methodologies that are focused on improving the utility of knowledge by eliminating poverty. Bearing in mind the high poverty levels and poor agricultural production which, according to this study, is depended upon by 88 (98%) of the respondents, there is dire need to explore other income generating ways for Chakol smallholder farmers such as bee-keeping which can be carried out even on small unproductive land .

Another key area where focus is required is an assessment of the best way of linking farmers to markets. The incomes generated can then be channelled back to improving the degraded soils, since it is clear that the use of mineral fertilisers for the replenishment of Chakol soils is inevitable to supplement the insufficient organic fertilisers available.

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APPENDICES

A. INDIVIDUAL FARMER QUESTIONNAIRE

An Assessment of the Utility of Soil Fertility Management Knowledge among Smallholder Farmers in Chakol, Kenya.

Background Information

Questionnaire no : …………………………

Village: …………………………..

Date: ……………….

FEI participant……………. Non-FEI participant…………….

Informant Background

1. Name of house hold head ……………………………………
2. Name of respondent if not the household head ……………………….

3. Age: ………………..
4. Gender: Male ☐ Female ☐
5. Marital Status
   a. Married ☐
   b. Single ☐
   c. Widow(er) ☐
   d. Divorced ☐
   e. Other ☐

6. Household size / no. of children: Boys:…………… Girls:………………….

7. Level of education?

a. Primary ☐
b. Secondary ☐
c. Informal education ☐ (specify ………………..)
d. College ☐
e. University ☐
f. None ☐

8. What is/are your source(s) of income?

	Income source	**% of Total income**
1.		
2.		
3.		
4.		
5.		

Farm Information

9. What is the total acreage of your farm? …………………. (acres)

a. What is the portion under crops? -----------------------------(acres)

Name the crops

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b. What is the portion under grazing? …………………….(acres)

Name of animal	No. kept

c. Other land uses?

10. How do you identify a fertile and infertile soil?

	CRITERIA	
	Indicators	Source of knowledge
Fertile soils	1. 2. 3. 4. 5. 6. 7. 8. 9. 10.	1. 2. 3. 4. 5. 6. 7. 8. 9. 10.

Infertile soils	1. 2. 3. 4. 5. 6. 7. 8. 9. 10.	1. 2. 3. 4. 5. 6. 7. 8. 9. 10.

11. For how long have you been farming the acreage stated above?

12. In your own opinion has the soil fertility of your farm improved / declined since you started farming?

Improved ☐ Declined ☐

a. What do you suppose caused the above stated change?

13. What are your sources of farm labour?

    a. Self ☐
    b. Family ☐
    c. Hired labour ☐
    d. Others ☐

Soil fertility practice / input selection and utilisation

14. a) What practices do you use to fertilise your farm? (Answer where applicable)

	Recent season practiced	**Fields applied to**	**Source-Animals/plants (Name them)**	**Preparation method**	**Area of application**	**Why area applied**	**When practice done**	**Reason for use/non-use**
Soil fertility Practice								
1. Legumes (N-fixation)								
2. Crop residue incorporation								
3. Rotation								
4. Biomass Transfer								

5. Natural Fallows								
6. Improved Fallows								
7. .Burning								

14. b) What inputs do you use to fertilise your farm? (Answer where applicable)

	Recent season practiced	**Fields applied to**	**Source-Animals/plants (Name them)**	**Preparation method**	**Amount applied**	**Why amount applied**	**When practice done**	**Reason for use/non-use**
Soil fertility input								
1. FYM								

2.Compost								
3. Mineral Fertilisers								

Knowledge and Knowledge Networks

15. What are your sources of soil fertility knowledge? (Answer where applicable)

		Sources of Soil Fertility Information					
		Researchers	Extension	Neighbours	Written Material	Exchange Programs	Others
	Specify source	-----------	-------------------	N/A	-------------	--------------	
a)	What learnt						
b)	Used knowledge (yes/no)						
c)	How did you use knowledge?						
d)	Advantages of knowledge						
e)	Disadvantages of knowledge						

B. CHECKLIST FOR FOCUS GROUP DISCUSSIONS

1. How has the soil in Chakol changed since the 1970s?
2. What do you think has caused this change in the soil?
3. How has the change in soil health affected agriculture in Chakol?
4. How do farmers differentiate between fertile and infertile soils?
5. Are soils in Chakol fertile or infertile? Why?
6. What were the common soil fertility management technologies in Chakol
   a) 25 years ago?
   b) Currently?
7. What brought about these changes (in 6. above) in soil fertility management practices and inputs?
8. How do local farmers select the soil fertility technologies to be applied?
9. How do local farmers acquire the knowledge on the roles of various soil fertility management technologies?
10. What are the advantages and disadvantages of the above named technologies?
11. How do local farmers determine soil fertility management input rates to be used on their farms?
12. How has soil fertility research in this area affected agricultural productivity?

C. CHECKLIST FOR KEY INFORMANTS

Interview schedule for extension agents and research scientists

1. How long did / have you worked in Chakol Division?
2. In what capacity did / have you worked?
3. What soil fertility knowledge have you disseminated to the farmers in the community?
4. How would you rate the farmers' response to the introduction of this knowledge?
5. What are the problems you encounter in the dissemination of this knowledge?
6. In your own opinion, do you think farmers in Chakol know what soil nutrient (N/P), is missing in their farms? (Explain).
7. What are the most common soil fertility management inputs used by farmers in Chakol?
8. What are the most common soil fertility management practices used by farmers in Chakol?
9. What criteria do you think farmers use when selecting the soil fertility input or soil fertility practice to employ? (Explain).
10. What constraints do farmers say they face in the utilisation of the various soil fertility management technologies?
11. How would you rate the impact of the soil fertility knowledge that you have disseminated to the farmers?
12. What suggestions would you make to improve soil fertility knowledge and its adoption for better soil fertility management by farmers in Chakol?