USING FARMER FIELD SCHOOL APPROACHES TO OVERCOME LAND DEGRADATION IN AGRO - PASTORAL AREAS PROJECT.

Land Use Practices In Mbeere District: Biophysical And Socio Economic Challenges, Copping Strategies And Opportunities: A Baseline Survey Report

Gachimbi, L.N., Kamoni, P.T., Wanjogu, S.N,, Macharia P.N and Gicheru, P.T

28th June 2007

Table of contents

LIST OF ABBREVIATIONS

ASALs	Arid and Semi Arid Lands
CBS	Central Bureau of statistics
DAREP	Dryland Applied Research and Extension Project
FFS	Farmer Field Schools
INM	Integrated Nutrient Management
ITC	Inter Tropical Convergence
KARI	Kenya Agricultural Research Institute
LUZ	Land Use Zone
MALD & M	Ministry of Agriculture Livestock Development and Marketing
MoPND	Ministry of Planning and National Development
NARL	National Agricultural Research Laboratories
SAPs	Structural Adjustment Programmes
SWC	Soil and Water Conservation

1. INTRODUCTION

Despite spirited efforts towards industrialization by the year 2020, agriculture still remains the engine for economic growth for Kenya. It is the main source of food and provides employment, foreign exchange earnings and raw materials for emerging industries however, the agricultural sector in Kenya faces daunting challenges in providing high quality and sufficient food to support the continuously rising rural population. As the increasing population continues to outstrip the available food supply, there is considerable anxiety that food inequalities will continue to worsen not only in Kenya, but also in other developing countries as well **(Pretty *et al.*, 1996)**. These improvements in productivity will, however, not be achieved without addressing the fundamental biophysical root cause of dwindling productivity-that is land degradation.

The agricultural frontier in Kenya is mainly the high agricultural potential areas, which only supports 20% of the total landmass in the country, while the rest of the landmass (80%) fall within the classification of Arid and Semi Arid Lands (ASALs). Although the needs of the high agricultural potential areas of Kenya have, to a great extent, been met through research and extension, the ASALs especially agro pastoral areas have not received sufficient and comparable attention, and the traditional production systems have benefited little from decades of agricultural innovations or appropriate technologies. Thus per capita food production has been on the decline. The declining per capita food production is intrinsically linked to agricultural stagnation, degradation of natural resource base, increasing population pressure, over stretched extension service and poor research linkages, weaknesses in institutional frameworks and factors related to challenges in the management of biophysical and policy environment **(Hilhorst and Muchena, 2000)**. Some authors have postulated that migrant populations from high agricultural potential areas to ASALs are partly responsible for the continued degradation of natural resources in the marginal areas due to the adoption of inappropriate farming technologies and the struggle for a living without conserving the natural resource base **(Gachimbi *et al.*, 2004 and Jager *et al.* 2005).**

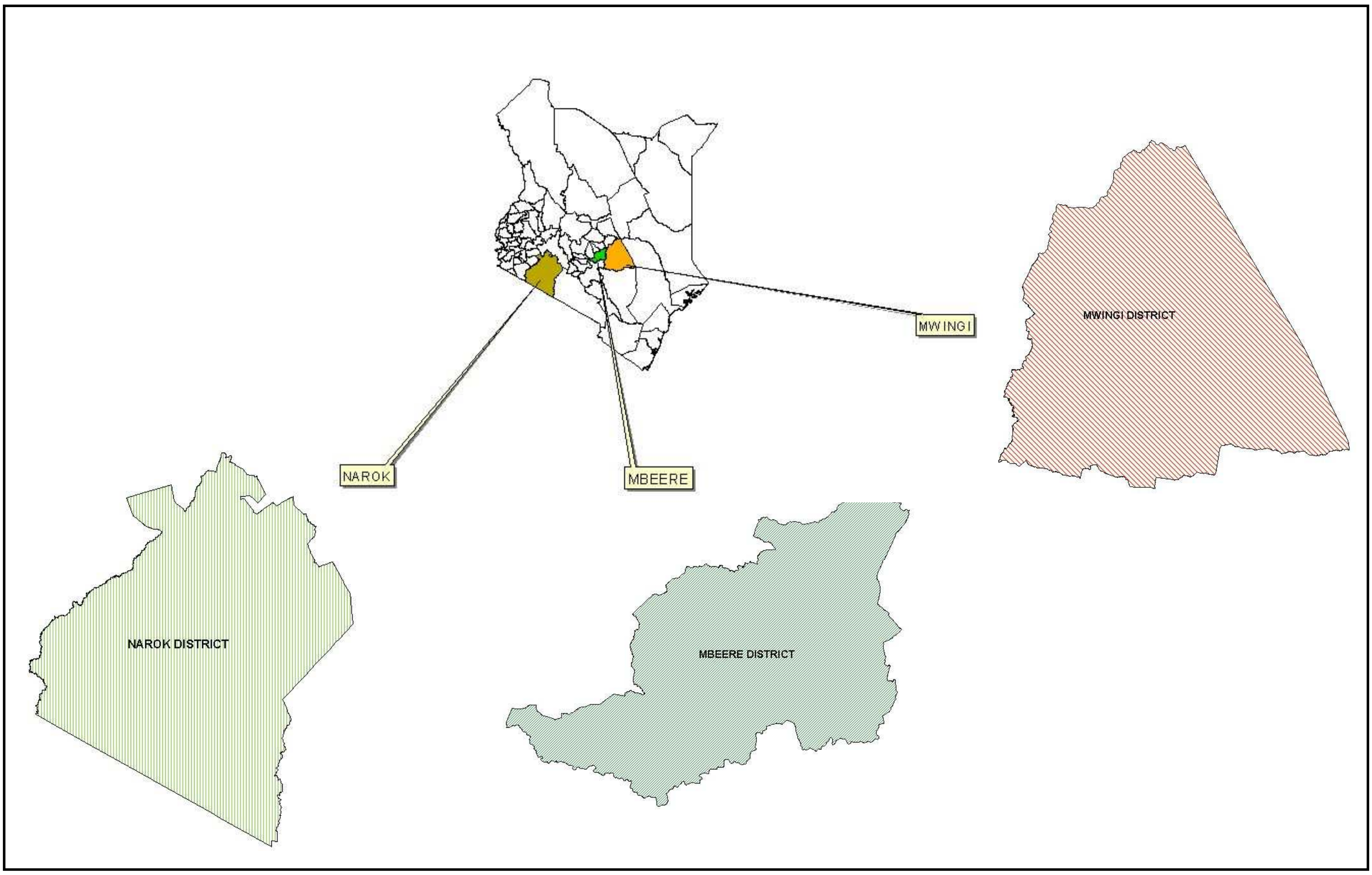
Possibilities of addressing the agricultural challenges in the ago-pastoral areas lie in the promotion of appropriate agricultural technologies fitting into farmer’s socio-economic circumstances and the prevailing biophysical environment. Understanding the dynamics of these environments can act as an impetus to promoting appropriate technologies and to increasing food production.

The objective of the baseline study is to unearth current land use practices challenges and opportunities in the semi-arid areas of Mbeere District, Eastern Province of Kenya. Chapter 2 of this report identifies the location of Mbeere District while the biophysical and socio-economic farming environments are presented as chapters 3 and 4 respectively. Chapter 5, 6 and 7 give analyses of existing land use and their impact on land degradation, livestock and soil fertility management in that order. The output of the review is envisaged to provide baseline information and to act as a basis for testing and developing integrated nutrient management technologies commensurate with ago-pastoral faring systems socio-economic environment through Farmer Field Schools (FFS) approach.

2. LOCATION OF MBEERE DISTRICT

Figure 1 presents the location of Narok, Mwingi and Mbeere pilot Districts in Kenya. Mbeere District is located in Eastern province of Kenya and lies between Latitudes 0^{o} 20' and 0^{o}50' South and Longitude 37^{0} 16' and 37^{0} 56' East. The District was curved out of Embu District in 1996.

Figure 1: Map of Kenya showing location of pilot Districts



3. THE BIO-PHYSICAL ENVIRONMENT

3.1. Area of the District

The District has a total area of about 2093 Km^2 with four divisions Gachoka, Siakago, Evorore and Mwea. Gachoka is the largest division in the district while Siakago is the smallest **(Table 1)**.

Table 1: Area of Mbeere District by Division

Division	Area (Km^2)	Percentage of the total
Siakago	365.3	17.5
Evurore	410.0	19.6
Gachoka	800.3	38.3
Mwea	514.9	24.6
Total	2,092.5	100.0

Source: CBS, 2001.

3.2. Climate and Agro-ecological zones

The district slopes in a Northwest to South East direction. Its altitude ranges from 1200m A.S.L. to about 500m A.S.L on the Tana River basin. The district is served by five permanent rivers namely Tana, Rupingazi, Thuci, Thiba and Ena.

The district has a bimodal pattern of rainfall with the long rains falling between March and June while short rains are experienced from October to December. The rainfall is however not very reliable and it ranges between 500 and 1100mm per year. Most parts of the district receive less than 550mm rainfall per year giving the area a marginal status. The extensive altitudinal range of the district influences the temperature, which ranges from 15^oc to 30^oc.

The district can be classified into a medium potential and marginal land with the latter taking up a greater part. The Central belt of the district, which includes parts of Gachoka, Siakago and Evurori divisions, has good black and red soils whose fertility ranges from low to moderate. The soils are generally sandy, blackish grey and reddish brown. Cultivation in this region however takes place mostly on the better-watered areas along the riverbeds. The soils around the hills in parts are mostly rocky and hence difficult for district are the Mwea plains where the land is generally flat. Soils in this region are mainly the black cotton type, which has low to moderate natural fertility.

The district is covered by three main agro-ecological zone the marginal cotton zone (LM4) covering the upper parts of Siakago and Evurore divisions. The lower midland livestock millet zone (which covers the central belt of the district extending to Mwea plains and to the Southwest) and the lowland livestock millet zone (LM5) which covers the Eastern parts of Siakago and Evurori divisions in the north Western part towards the border with Embu and

Kirinyaga district, there are pockets of medium potential agro-ecological zones. These include cotton zone (LM3) in parts of Gachoka and Siakago division, the sunflower maize zone (UM4) and the marginal coffee zone (UM3) around Siakago market. There is also the marginal cotton on the South Western parts around Karaba.

Table 2. Agro-Ecological zones

Agro-ecological zone	Location	Altitude	Temp °C	Rainfall (mm/yr)	Size/Area (Km^2)	%
UM3 marginal coffee zone	South of Siakago market towards Maathai	1280-1460	20.7-19.6	1000-1250	20	1
UM4 Sunflower/maize zone	Upper parts of Siakago and Gachoka divisions	1280-1400	20.7-20.0	100-1000	51	24
LM3 Cotton zone	Upper parts of Gachoka (Mbeti) & Siakago (Riandu) divisions	1070-1280	22.0-20.7	900-1000	225	10.6
LM4 Marginal cotton zone	Upper parts of Siakago, Kiritiri, & Evurore location	980-1280	22.5-21.0	280-900	339	16
LM5 – Lower Midland Livestock/millet zone	Covers Evurorei & Ndurumori locations of Evurori division and Mutitu location of Siakago & almost the whole of Mwea division	830-130	23.5-21.7	700-900	1,247	60
L5 Lower Livestock/zone	Kiambere location of Gachoka and Ndurumori location of Evurori division	760-830	23.9-23.5	640-700	215	10
Total					**2,097**	**100**

Land use and production systems

Table 3: Categories of Agricultural Land

Total Land Area	2,097KM^2
Agricultural land	1,690KM^2
Medium potential land	840KM^2
Low potential	1,260KM^2
Irrigated area	19.5KM^2
Potential irrigation area	1,050KM^2
Total arable land	9944.9KM^2
Total area under crops	400KM^2

NB Most of the medium potential land is in upper Gachoka and upper Siakago. Lower parts of Gachoka and Evurore division consist of low potential land. Over 95% of the irrigation area is along the five main rivers.

Table 4: Land uses

Total land area	2,097KM^2
Forest land	37.7KM^2 (un-gazette forests) (Kiang'ombe 21.04Km^2, Kianjiru 10.04Km^2, Kiambere 6.34 Km^2)
Game reserves	42Km^2 (Mwea National Reserve)
Large scale farms	20.55Km^2
Small scale farms	1,980Km^2
Total population	172,226 Persons
Population density	82 Persons/KM^2

Land Categories/ Land Uses

Mbeere district has a lot of potential for farming. The major constraint is water and for this reason growing of drought resistant crops is encouraged. Where possible irrigation schemes have/are being developed to enhance food production. A case in point is Kathigi/Ishiara and Kiambindu irrigation schemes in Evurori division that are now producing export vegetables.

3.3. General Soil Characteristics

The soils in the district are variable and are generally low in fertility. Soils in the middle of the District are well drained, very deep to dark red friable clay (nito-rhodic Ferralsols, rhodic Ferralsols). A major part of the district is covered by well drained, shallow to very deep, dark reddish brown to yellowish brown, loose to friable, loamy sand to sandy clay loam, in places rocky and stony (Ferralic Arenosols; with orthic Ferralsols and Acrisols), **(Van de Weg and Mbuvi, 1975; Jaetzold and Schmidt, 1982)**. The lower parts of the district, Mwea plains, are covered with black cotton soils of low to moderate fertility (pellic Vertisols).

Soil and water conservation measures coupled with water harvesting techniques are practiced in parts of the District to reverse land degradation. These include physical measures such as stone lines and terraces as well as biological and cultural measures such as trash lines and grass strips among others.

3.4. Farming systems

The district is covered by three main agro-ecological zones **(Jaetzold *et al* 1982)**: The marginal cotton zone (Lower midlands, LM 4), the Lower midland livestock-millet zone (Lower Midlands, LM 5) and Lowland livestock millet zone (Lowlands, LM5)**.** Except for a small pocket of medium potential agro zones towards the border with Embu (LM 3, UM3 and UM4), the District is largely a low agricultural potential zone (rain-fed conditions), hence crop production is a difficult venture. Food crops such as maize, millet, sorghum, beans, cowpeas, green grams, cassava and bananas are grown mainly for subsistence. The main cash crops grown are cotton, tobacco and to a lesser extent, sunflower. However, marketing problems has hampered cash crop production especially cotton. In view of the few cash crops grown, most of the food crops, especially green grams, cowpeas and sorghum play the dual role as both food and cash crops, upon sale of surplus in good cropping seasons.

Livestock species kept in the District are mainly indigenous breeds, which are adapted to the marginal conditions prevailing in the District. They are mainly kept under free-range system and include cattle, sheep, goats and poultry. Dairy cattle, dairy goats and exotic poultry are kept in limited pockets of the District.

4. THE SOCIO-ECONOMIC ENVIRONMENT

4.1. Population

The district is sparsely populated with a population density of 82 with a range of 37-93 persons per km^2 **(CBS, 2001).** Siakago and Evurore Divisions are the most densely populated divisions of the District with 93 and 90 persons per km^2 respectively **(Table 5)**. 63% of the total population live below poverty line.

Table 5: Population characteristics of Mbeere District

Division	Male	Female	Total	Households	Density (persons/km^2)
Siakago	16,656	17,674	34,330	7,852	93
Evurore	16,764	20,077	36,841	7,677	90
Gachoka	28,772	30,330	59,102	12,905	74
Mwea	19,693	20,987	40,680	8,602	79
Total	81,885	89,068	170,953	37,036	82

Source: CBS, 2001.

The lower part comprises semi-arid regions with less than 100 people Km^{-2}. These are areas that are currently experiencing the greatest population change, compared with the high potential agricultural areas, with a natural rate of increase of 3.5 to 4% in East Africa and a higher actual growth rate due to migration from the crowded fertile areas of the highlands especially Embu (Nandwa 2003). Farm sizes in these regions are thus getting smaller, ranging from 16 to 2.5 ha per household (Gachimbi, 2002.), in East Africa. Traditionally, farmers have always grown maize (*Zea mays L*.), beans, sorghum, millet, cowpeas and pigeon peas. The migrants into the semi-arid regions have traditionally brought along with them crops more suited to the high potential regions, with no requisite change in production technology to optimize the production of these crops in the semi-arid regions.

4.2. Communication Network

The road network, postal and telecommunication services are inadequate and underdeveloped. The district has a total length of 800 Km of roads, out of which 78 Km (Trans-district road) is under tarmac **(MoPND, 1997)**.

4.3. Labour

Agriculture and off-farm activities employ 92% and 7% of labour respectively. The rest, 1% represents disguised unemployment level and members of the labour force who have migrated to other districts. The informal sector and formal sector employs 4% and 3% of the labour force respectively as detailed in the employment profile **(Table 6).** Off-farm income sources are limited in the district. Sources of off-farm activities include quarrying, sand harvesting, fishing, and small-scale business and public sector employment.

Table 6: Employment profile in Mbeere District for the year 1999

Sector	Percentage
Agriculture (Crops and Livestock)	92.0
Other Rural self employment (off-farm)	3.0
Wage employment (Off-farm)	3.8
Urban self employment (Off-farm)	1.0
Others e.g. migration	0.2
Total	100.0

Source: Mbeere District Development Office, Siakago, 1996

Table 7 shows that more men were engaged in paid labour activities than females in 1999. However, females provided 60.2% of labour (unpaid) for farming family farms about 52.8% of females were economically inactive (not working and not available for work due to various reasons).

Table 7: Gender desegregation of labour force participation in Mbeere (1999)

Gender	Worked for pay	Unpaid workers		Unemployed persons	Economically inactive	Not stated	Total
		In family business	In family farms				
% Male	68.2	46.1	39.9	56.8	47.2	53.3	47.7
% Female	31.8	53.9	60.2	43.2	52.8	46.7	52.3

Source: CBS, 2001; Persons aged 5 years and above.

4.4. Income and poverty levels

The main sources of income in the district are agriculture and livestock activities and the disparities in earnings are insignificant across the various Divisions. Mbeere District Prevalence of Rural Food Poverty is estimated at 57.4% while Rural Poverty gap and absolute poverty are estimated at 26% and 63% respectively **(CBS, 2001).**

5. CROP PRODUCTION TRENDS, CHALLENGES AND OPPORTUNITIES

5.1. Rainfall trends

In the district, food production takes place, mainly, under rain fed agriculture, which is the major means of survival. However, low and erratic rainfall remains the overwhelming production constraint in the district and is a major reason for food insecurity and high risks of crop failure. This has been corroborated by studies carried out in other parts of Eastern Kenya, which have demonstrated the difficulties involved in exact correlation of rainfall characteristics with crop yields **(Konini, 1988)**. Rainfall variability, amounts and low soil moisture holding capacity are the most important characteristics influencing agricultural production in the district. However, the extent to which each of these factors, and or their combinations, influence production levels depends on existing micro-variability. In most parts of the district, it is the distribution of rainfall that is a major constraint to agricultural production rather than total amounts received **(MoPND, 1997)**. It has also been reported that the onset of rains and planting dates have a strong positive correlation with yield variability and yield losses in such dry land environments **(Onyango and Muriuki 1996)**.

5.2. Soil and Water Conservation and Water Harvesting Practices

The topography in Mbeere is variable and areas with slopes as high as 30% or more are commonly used for crop production despite the unstable soils exposing them to severe soil erosion and nutrient depletion.

Many of the soils in the Mbeere are deficient in some essential mineral nutrients especially phosphorous (P) and nitrogen (N) as shown in figure 2 and as described elsewhere **(Okalebo, 1987; Hikwa *et al*, 1998**. Low soil fertility (especially P and N deficiency) is a major biophysical constraint to successful agriculture in semi-arid areas of East Africa (Yates and Kiss, 1992;).

In the past, soil conservation has been advocated as a necessary starting point to raise crop yields. Soil erosion has conventionally been perceived as one of the main causes of land degradation and the main reason for declining yields in tropical regions. Based on these assumptions, conservation measures were directed at three main components from 1950s (**Wenner, 1980):**

- Physical works; Cut off drains and channel terraces to catch, disposal and prevent damage by run-off.
- Pressures to stop people from deforesting the area and to reduce the number of grazing animals by designating Mbeere to be grazing areas.
- Planning of different land uses according to Land Use Capability Classifications based on the assessment of different degrees of the erosion hazards Tea and dairy with subsistence crops next to the forest,

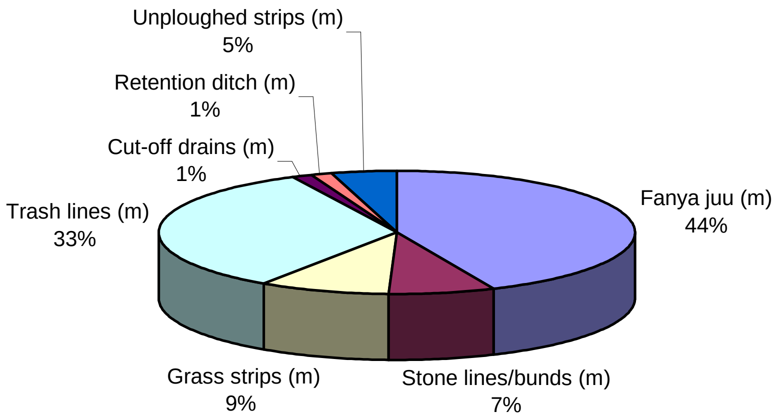
coffee, maize, dairy or a combination of these in the lower midland zones ($LM_{4-5)}$ to grazing.

Integrated Nutrient Management (INM) and improvement in crop production require adoption of improved rainwater management practices that integrates conservation of water as well as the soil and the available nutrients. **Buresh *et al*., (1997)** have further stated that the effectiveness of INM practices and technologies in enhancing food production is greatly influenced by accompanying practices and technologies such as soil and water conservation practices and sound agronomic practices. These practices increase soil water content supply, reverse nutrient loss through erosion, mitigate against deteriorating soil physical structure and contribute to successful crop production.

For successful crop production, Soil and Water Conservation (SWC) practices for soil erosion control and moisture retention can be augmented with judicious water harvesting practices. Soil moisture retention practices aim at preventing runoff and keeping rainwater, as much as possible, in the place where it falls. Water harvesting for crop production involves collecting, concentrating, and directing various forms of run-off (from uncropped land) to areas where crops are grown and to areas where such water can be used productively **(Duveskog, 2001)**. Water can be harvested within-fields or from external catchments such as uncultivated areas (roads, grazing areas etc.).

Trends in implementation of soil and water conservation practices in Mbeere District are presented in **Figure 2**. During the period under review, practices such as bench terraces, narrow based terraces and artificial waterways were not reported. Major soil and water conservation practices in the district include terracing (fanya juu, cut off drains and retention ditches), stone lines, grass strips, trash lines, unploughed strips, river bank protection, contour bunds, negarim, semi-circular bunds, basins/9 seeds in a hole and plating pits. In addition to the above practices, gulley control using vegetative materials, gabbions and mixed materials are also being practiced. The dominant soil and water conservation practices in the district at farm level were *fanya juu* method of terracing and the use of trash lines.

Figure 2: Trends in implementation of SWC practices (1996-2001) in Mbeere District[1]



[1] Excludes river bank protection, contour bunds, nagarims, semi-circular bunds, basins/9 seeds in a hole and pitting

5.3. Irrigation

Another practice to ensure water availability to crops in Mbeere District is through irrigation. The District is served by five perennial rivers, whose irrigation potentials are underdeveloped **(Table 8 and Table 9)**. The rivers include Tana, Thuci, Thiba, Ena and Rupingazi. These rivers, together with the limited seasonal streams, earthdams, and springs in the district provide irrigation potential for small-scale:

- Group based horticultural gravity schemes;
- Group based horticultural pump-fed schemes;
- Group based food schemes; and
- Individual small holder schemes.

Other significant water resources in the district are dams, which serve to generate hydroelectric power. These dams include Kiambere, Gitaru, Kamburu, Kindaruma and Masinga, all of which are situated along the Tana River.

Table 8: Potential water sources for irrigation in Mbeere District

Division	Water source	Abstraction method	Potential crops
Evermore	• Edna River and Theca rivers • Gacavari, Kathegi and Rwiria streams	• Gravity • Pump fed	• Food crops • Horticultural crops
Siakago	• Ena River	• Pump fed	• Food crops • Horticultural crops
Mwea	• Tana, Thiba and Thuci	• Pump fed • Surface	• Food crops • Horticultural crops
Gachoka	• Rupingazi, Tana, Thiba • Earth dam • Mwiru stream	• Pump fed • Watering can	• Food crops • Horticultural crops

Source: District Agricultural Office Annual Reports, Mbeere (1996-2001)

Table 9 shows that only 15-22% of potentially irrigated land is being exploited in Mbeere district and those levels of exploitation of irrigation potential have not changed considerably since 1996. Gachoka and Mwea exhibit comparatively high levels of exploitation of irrigation potential for small-scale agriculture while the potential for irrigation in Evurore is the least exploited. It is estimated that 500 ha of land in the district is under small and large scale irrigation schemes **(MoPND, 1997)**

Table 9: Area under irrigation (ha) in Mbeere District, small-scale schemes

Division		1996	1997	1998	1999	2000	2001
Evurore	Potential (ha)	1548.0	693.0	693.0	693.0	633.0	633.0
	Irrigated (ha)	60.0	55.6	55.6	55.6	58.0	63.0
	%irrigated	4.0	8.0	8.0	8.0	9.0	10.0
Siakago	Potential (ha)	126.0	63.0	83.0	83.0	144.0	144.0
	Irrigated (ha)	6.0	12.3	17.3	17.3	22.5	27.0
	%irrigated	5.0	20.0	21.0	21.0	16.0	19.0
Mwea	Potential (ha)	1604.0	1900.0	1900.0	1900.0	1250.0	1250.0
	Irrigated (ha)	420.0	475.0	475.0	475.0	139.0	139.0
	%irrigated	26.0	25.0	25.0	25.0	11.0	11.0
Gachoka	Potential	588.0	414.0	414.0	414.0	663.0	663.0

	(ha)						
	Irrigated (ha)	147.5	135.4	135.4	135.4	140.0	179.4
	%irrigated	25.0	33.0	33.0	33.0	21.0	27.0
District	Potential (ha)	3866.0	3070.0	3090.0	3090.0	2690.0	2690.0
	Irrigated (ha)	633.5	678.3	683.3	683.3	359.5	408.4
	%irrigated	16.0	22.0	22.0	22.0	13.0	15.0

Source: District Agricultural Office Annual Reports, Mbeere (1996-2001)

The underutilization of the water resources in the district is largely due to inability of the local farmers to acquire enough cash capital input. This situation is not any different from many parts of sub-Saharan Africa where it is reported that there is generally low levels of adoption of modern technologies (such as irrigation) for land intensification **(Badiane and Delgado, 1995).** FAO (1986) has further reported that the contribution of irrigation to food supply in sub-Saharan Africa is limited at regional scale despite the emerging large scale, centralized technology driven schemes and that the performance of these schemes has been disappointing with low returns to investment. They suffer from various administrative, financial and technical constraints characterized by salinization and degradation of the watersheds as a result of siltation and other problems like outbursts of weed growth, limited skilled personnel and capital needed to maintain equipment.

5.4. Trends in Crop Production

5.4.1. Major crops in the district

Crops grown in the district are mainly cereals, pulses, root crops, and horticultural crops. Tobacco, cotton, and *miraa* (*Catha edulis*) are also grown. **Table 10** shows crops statistics for year 2005.

Table 10: Crops statistics for March/April 2005 rains

Crop	Target Hectarage	Achieved Hectarage	Target production		Achieved production		Comments
			Bags/ha	Bags	Bags/ha	Bags	
Maize	15,000	13,000	12	18	0	0	Tussling & milk stage
Sorghum	500	450	10	15	0	0	Not major season
Millet	500	450	10	15,	0	0	Not major season
Beans	7,000	6,300	8	20	0	0	
Cowpeas	7,500	6,750	8	16	0	0	Red variety linked
Green grams	5,000	4,500	6	30	0	0	N26 preferred
Pigeon peas	2,400	2,100	8	19	0	0	Flowering
Soy beans	0	0	0	0	0	0	
Cassava	400	250	10 tons	40	0	0	Making tubers this season
Sweet potatoes	62	51	10 tons	62	5	225 tons	Suitable crop but limited to few

							farmers
Irish potato	3	2	3	90	0	0	Few framers plant
Dolichos	250	175	4	10	0	0	
Sunflower	0	0	0	0	0	0	Marketing problem
Cotton	1,000	4,000	0.5 tons	500kg	0	0	Harvesting of bottom land crop
Chick peas	50	20	4	2	0	0	Mainly in Mwea division in black cotton soils
Tobacco	0	0	0	0	0	0	Not planted this season
Macadamia	4	0.4	0.7 tons	2.8 tons	0	0	Mainly is Siakago division

Farmers in tobacco growing areas plant maize where there they had planted tobacco with the practice of using the same holes to capture the advantage of the fertilizer residue in tobacco.

Prices of most foodstuffs are starting to rise since farmers are clearing their food stocks from their stores. About 60% of the farmers are now relying on purchased foodstuffs. **Table 11** shows market prices for major commodities in the District.

Table 11: Market prices for major commodities in June 2005

Crop	Unit	Price Kshs at Siakago market	Price Kshs at Ishiara market
Maize	2 kg tin	45	40
Sorghum	2 kg tin	60	50
Bulrush millet	2 kg tin	70	50
Finger millet	2 kg tin	80	-
Prosso millet	2 kg tin	75	-
Mwitemania beans	2 kg tin	75	75
Rosecoco beans	2 kg tin	90	80
Cowpeas	2 kg tin	65	60
Green grams	2 kg tin	80	80
Green grams N26	2 kg tin	85	80
Dolichos lablab		-	-
Irish potato	100 kg bag	3000	3000
Irish potato	2 kg tin	60	60
Sweet potato	3 roots	20	20
Cassava	1 root	20	20
Pigeon peas	2 kg tin	-	-
Arrow roots	4 roots	-	30
Yams	1 root	-	35

The main cereals grown include maize, sorghum and millet while beans and cowpeas are the main pulses. Major root crops include cassava and sweet potatoes, which are grown as security crops. Crops being promoted as drought escaping include cowpeas, pigeon peas, green grams, sorghums, millets and cassava, among others **(DAREP, 1994 and 1995)**

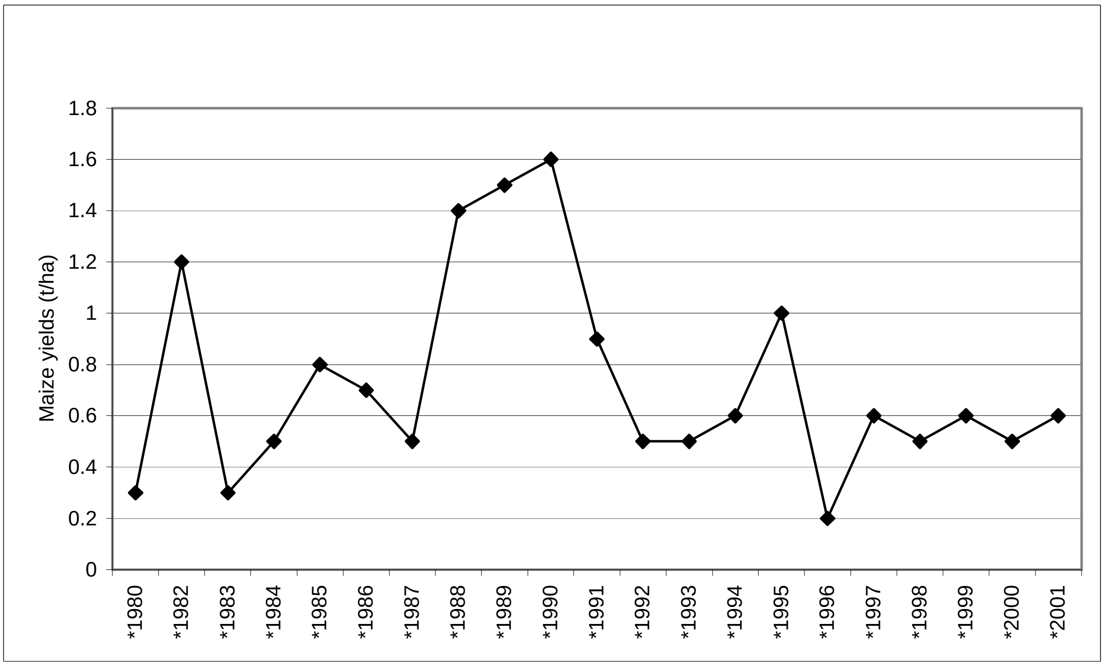
5.4.2. Selected cereals

5.4.2.1. Maize

Although a number of food crops are grown in the district, maize is the most important, hence its significance in maintenance of national food security **(Anon, 1981)**. Maize has witnessed a great technological transformation in Kenya compared to other cereals such as sorghum, which were introduced long before maize. This is mainly because of introduction of hybrids and composite varieties **(Hassan and Karanja, 1995)**. However, yield trends of maize at farm level is low especially among the small scale farmers with resource limitations**. Figures 3** present trends in yields in Mbeere District. Data for the period1980-1990 are for the broader Embu District before subdivision in 1996. Data for 1991-1995 were derived from administrative divisions that make up Mbeere District **(MoPND, 1997)**. The area under maize has been fluctuating and decreasing and the same for maize yields.

Maize yields have been decreasing since 1990. Some signs of recovery were however, observed in 1997. Since then, maize yields have been more or less stagnating. Similar trends for yields of major food crops have been reported at national levels, in spite of the considerable efforts that have been made to increase productivity **(FAO, 2001)**. These observations have been further corroborated by the work of **Gitari et al. (1996)**, who reported that there is a significant yield gap between maize yields at farm level and that of on-station work in Eastern Kenya. The average yields of maize of 0.5 ton ha^{-1} for Mbeere (1996-2001) were far below the expected yields. The average maize yield in Mbeere District range between 1.0 and 1.5 tons ha^{-1} against a research potential of 5.0 tons ha^{-1} **(KARI, 1994)**.

Figure 3: Trends in maize yields in Mbeere District



1980-1990: Broader Embu District before sub-division; 1991-1995: Data synthesized for administrative divisions that presently make up Mbeere District.

5.4.2.2. Sorghum and millet

Sorghum is an important food security crop in Mbeere District. In the policy sphere, the role played by drought tolerant crops such as sorghum in food security has been officially recognized **(Sessional paper No. 1, 1986)**. Sorghum is used by farmers in preparing various foodstuffs such as porridge and *ugali*. It is also used for local brewing.

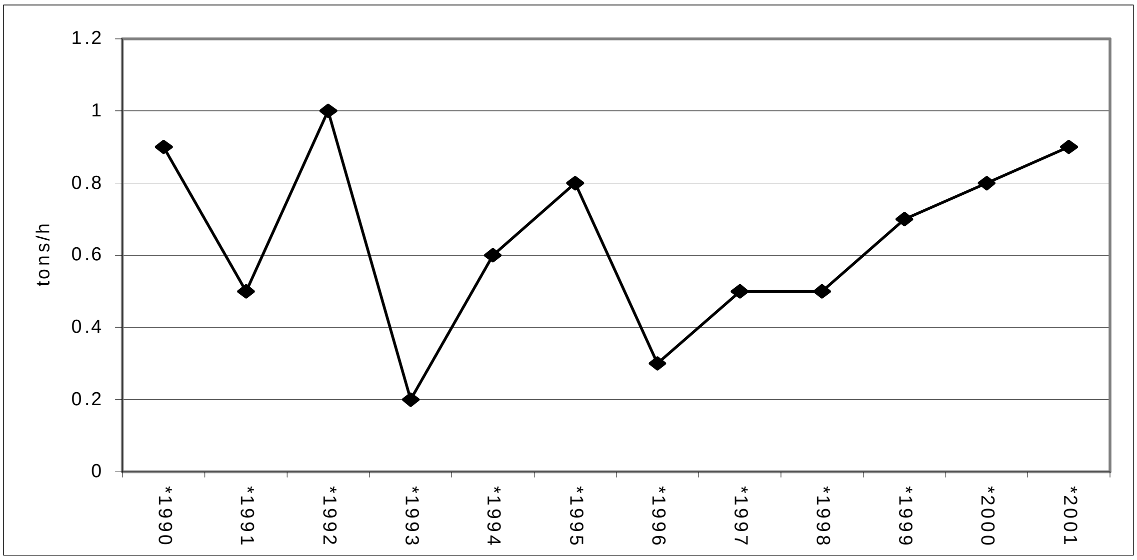
Sorghum production in Mbeere District is low and there exists a significant yield gap between farmer's production levels and research potential yields of 3-4 tons ha^{-1} **(Ogecha, 1995)**. The yields have been declining with some signs of recovery from 1996. The average yields of sorghum obtained in this review for the period 1991-2001 (Mbeere District) was about 0.7 tons ha^{-1}. Poor management practices (e.g. low or non application of mineral fertilizers) and socio-cultural factors have contributed to these low yield levels. This includes problems in managing birds, the limited commercial demand and poor marketing channels, colour, taste and non-availability of improved seeds at farm level. Other related problems are insufficient labour during peak periods and limited utilization of sorghum grains and bi-products. It has been reported that farmers prefer sorghum varieties that are not vulnerable to bird damage, those that are sweet (palatability), white coloured, high yielding, and those that do well under low input conditions in addition to having good threshability **(Wanyama *et al*., 1996)**.

New sorghum varieties currently being promoted in the district are Serena, Sres and KARI Katumani 1. The land allocated to these improved crop varieties is low compared to local varieties in Mbeere District. Only 5%, 3.2%

and 2.1%, respectively, of the land under sorghum is allocated to KARI-Mtama 1, Serena and Seredo improved varieties respectively **(Matiri *et al*., 1999)**.

Millet is one of the food security (cereal) crops grown in Mbeere District. Trends in millet production has been on the decline and fluctuating in the district **(Figure x)**. However from 1996, there appears to be improvement in yield production. The low millet yields are partly attributed to low adoption of practices such the use of mineral fertilizers, manure and line planting in addition to growing of poor yielding cultivars among others. Of the total land allocated to millet production, only 2% to 2.6% is allocated to new millet improved varieties such as KPM 1, KPM2 and ICRISAT (see Appendix 2). A greater part of the district is still under local varieties such as *"Kimbeere"* and *"Ciakaungi"*. Other local varieties such as *"Kiraka"* are also grown, but are mainly found in the neighbouring region of Meru South. In adoption of millet varieties farmers consider earliness, drought tolerance, threshability when dry, panicle compactness, bird damage, yield, colour, taste and grain size to be important criteria **(Ngoroi *et al*., 1999)**.

Figure 4: Millet production trends in Mbeere District



1980-1990: Broader Embu District before sub-division; 1991-1995: Data synthesized for administrative divisions that presently make up Mbeere District.

5.4.3. Selected legumes

5.4.3.1. Beans

Beans are important food crops grown in Kenya and rank second in cultivated area to maize. It is a major source of protein in the diet of many Kenyans. Probably, the common beans (*Phaselous vulgaris* L.) have been cultivated in East Africa for the last three centuries, although existing records date back to only the turn of the century **(Wachira, 1996)**. National average bean yields vary from 0.3-0.4 ton ha^{-1} in farmers fields compared to the potential yield of

2.0 tons ha^{-1} for bush beans (**Okoko and Makini, 1999)**. Factors contributing to low bean yields include diseases, pests, low soil fertility and use of poor yielding seeds **(Okoko and Makini, 1999; Songa et al., 1999)**.

5.4.3.2. Cowpeas

Cowpea is an important food security crop grown in the semi-arid regions of Mbeere District **(Sutherland *et al*., 1994; Muruli *et al*., 1980)**. It is the second most important legume crop in Kenya after beans, with 85% of its production being confined to the semi-arid lands of Eastern Kenya. The crop is a major source of cheap and high quality protein in addition to being a source of income. It is consumed as grains and as green leaves with excess produce sold in the local markets **(Anyango *et al*., 1999)**. Cowpeas improve soil fertility through nitrogen fixation, supply vegetables while growing and also provide dry seed when mature **(DAREP, 1995)**.

The adaptation of cowpeas to the semi-arid areas is due to its morphological as well as biochemical qualities. The deep root system and early maturity of the crop are some of the qualities that make the crop adaptable to the hostile environment. However, the yields of local cowpea varieties are poor and this has prompted the introduction of high yielding cultivars. The average yield of cowpeas for Mbeere District was 0.5 tons ha^{-1}, which was below expected yields of 1-2 tons ha^{-1} for improved varieties **(MoPND 1997)**.

According to **Muthamia and Kanampiu (1996)** the criteria farmers consider in evaluating cowpea varieties are maturity period, grain size, pest tolerance, leaf appearance, seed coat colour, cooking time, taste of cooked cultivar, ability of the cooked product to keep overnight and market price.

The poor cowpea yield is attributed to many factors including the use of poor yielding varieties, low soil fertility and pests (e.g. Kiwi beetle and parasitic weed, *Alectra volgelii*) and diseases. Access to new varieties of seeds is a major problem. Some of the cowpea cultivars released in the past one decade have not been accessed by many farmers (**Muthamia and Kanampiu, 1986).**

5.4.4. Selected root crops

5.4.4.1. Sweet potatoes

Sweet potato (*Ipomea batatas*) is a major food security crop as it is drought tolerant and thrives in a wide range of soils and agro-climates (**Elwell, 1990**). It is also dual purpose as vines are used as livestock feed. However, sweet potatoes are highly perishable once harvested. Tubers store for a maximum of five days under normal conditions **(Miruka, 1999).**

An average sweet potato tuber yield in Mbeere is 7 tons ha^{-1} for the period, which is far below the yields of new potato varieties like KSP 20. Constraints to sweet potato production have been reported to be inadequate planting materials, drought, wild animals (squirrels, porcupines, wild pigs etc.), domestic animals (goats, sheep and cows) and sweet potato weevil (**Muthamia *et al*., 1999**). In some areas, the crop is also looked upon as a low status crop with little opportunities to generate income. **Nkonge et al., (1999)** have reported that farmers consider the following criteria in evaluating new potato varieties: drought tolerance, tuber numbers (yields), texture and taste, maturity period and storability.

5.4.4.2. Cassava

Cassava (*Manihot esculenta*) is an important crop in the arid and semi arid lands of Kenya. It is estimated that out of 70,000 ha planted with Cassava in Kenya, 5% is found in Eastern Kenya, where Mbeere District is situated **(FAO, 1984)**. Cassava is a hardy crop that can adapt to micro-variations in relief, soils, different cropping systems, infertile soils, little inputs and labour, and a long harvesting period. Thus, it is planted as a famine relief insurance crop and an emergency food reserve in the semi-arid areas of Mbeere District. Cassava provides carbohydrates, vitamins and minerals and its starchy roots produce more calories per unit land than any other crop **(Kanguha and Mailu, 1996)**.

The yields of cassava are low and have been stagnating from 1993. Average yields were estimated at 8 tons ha^{-1} during the period (1996-2001). Constraints to stepping up cassava production in Mbeere District include inadequate and unavailability of high yielding varieties and pests and diseases (especially Cassava Mosaic Virus). **Nkonge et al (1999)** have reported that farmers consider yields, storage abilities, taste and texture, and tolerance to pests and diseases as important criteria in accepting new varieties of cassava.

5.4.5. Crop Production Challenges and opportunities

The differences in crop yields between farmers' fields and on-station research can be attributed to various constraints, which are biophysical, or socio-economic in nature. Previous studies in this area have identified low soil fertility, low adoption of recommended varieties and low plant populations to be the main biophysical factors contributing to low maize yields at farm level **(Gitari et al. 1996)**. The limited cash availability within the farming households limits the use of essential inputs such as mineral fertilizers for crop production. It has been reported that in situations where finances are limiting, it is more profitable to invest in improved plant density than using hybrid maize seeds and high fertilizer application rates during short rains in Eastern Kenya. However, during long rains, investing in hybrid seeds and high plant density is more profitable than using high fertilizer application in Eastern Kenya.

Emerging efforts to address the declining maize yields in the district has been partly focused on introduction and promotion of new maize varieties with high production potentials **(**e.g. dry land hybrids, Katumani composite, Cargill C94141, FIDA-Seeds PAN 5355**)**. However, low adoption rates for these varieties among the resource limited small scale farmers suggest the need for a careful refinement of the technologies in addition to addressing socio-economic factors affecting adoption. Socio-economic factors affecting adoption of maize in Eastern Kenya and Mbeere in general have been underscored as the size of land holdings, amount of pollen grains shed, returns to investment, market infrastructure and consumption preferences **(Micheni and Gathama, 1999; Gitari *et al*., 1996)**. The latter includes grain size, texture, colour, taste and smell.

Overall box 1 shows a summary of crop production constraints and opportunities in Mbeere District.

Box 1: Summary of major crop production constraints and options for Increased food production

Constraints

- Limited accessibility to high yielding varieties.
- Low and variable rainfall.
- Declining soil fertility (low use of inputs).
- Exacerbation of pests and diseases.
- Poor market infrastructure.

Options and opportunities

- Increasing land under cultivation.
- Community bulking of high yielding seed varieties (seed bank).
- Addressing soil fertility constraints: recycling of manure, use of crop residues, use Of green manures and cover crops and adoption of agro forestry. Use of combinations of organic and inorganic inputs.
- Efficient water use: timing of planting, water harvesting and soil moisture retention techniques.
- Land intensification through irrigation where possible.
- Farm mechanization through increased use of oxen draught power to reduce labour demands for land preparation and weeding.
- Enhanced skills in integrated crop management (good farming practices, pest management, soil fertility management etc.).

5.5 Land Use and Implications on Biodiversity

Land use in Mbeere is characterized by certain specific land management activities like ploughing and weeding, use of manure and fertilizers, use of insecticides and herbicides. These different management activities have direct impact on the dynamics of vegetation due to disturbance. From a management point of view the land use could be categorized into three major types namely: livestock grazing, commercial mono-crop farming and subsistence mixed crop farming. Comparing species abundance between these systems showed that grazing systems have the highest plant diversity while cultivations of monocrops have the lowest (**Maitima *et al* 2004)**. The report also shows that, as land use intensification increases, cultivation replaces natural vegetation in agro-ecosystems and the number of species decline due to the loss of native species as weeds start to invade.

It is well known that land use change from more natural vegetation to one that is more intensively used has created ecosystem fragmentation to smaller patches that are more heterogeneous than the undisturbed continuum **(Reid et al. 1997, Foran et al. 2000)**. However, if the disturbance is much more intensive like in cultivation of horticulture, non-desirable plant species are not let to grow due to constant removal of invasive weeds and harvestable plant materials. The linear decline in the number of native species with land use change from polyculture to monoculture suggests that as land use changes from natural to grazing lands and to cultivation, there is always loss of indigenous species.

From the report it has been observed **(Maitima *et al* 2004**) that as land use intensity increases, plant cover decreases linearly. Although the number of plant species appears to increase before a continued decline as explained above, the plant cover shows a steady decline. In this analysis it was noted that as land use starts to intensify there is first a period of increasing plant diversity while the vegetation cover is decreasing. As dominant higher canopies (e.g. trees) are removed due to land use change there is a room for invasive species to grow in the lower canopies to cover the exposed areas but since these are structurally with less crown cover, the overall cover is generally reduced and hence high erosion when rainy season starts. This shows that although land use change from forests to woodlands to pasturelands appear to increase plant diversity in terms of species numbers, the loss of structural complexity and plant cover suggests land degradation. Examples highlighting the impacts of land management techniques on vegetation are discussed below.

Implications of changing vegetation structure on biodiversity conservation

Differences in the number, diversity and cover values of vegetation patches resulted from differences in land-use systems within the Mbeere. Land clearing for cultivation, integration of livestock and other uses have resulted into fragmentation of large and extensive areas of native vegetation. As farmers clear more land for agriculture, smaller cultivated fields coalesce to form larger fields thereby creating large homogenous patches of farmland. The rapidly growing population within Mbeere area has likewise led to intensification of agricultural activities and widespread sparse cultivation on the suitable regions in the lowland areas.

Substantial changes have been observed for different vegetation cover types such as bushed grassland, forests, pastures and cultivation. The remaining natural vegetation within the study area has become lone habitats for wildlife species outside the protected areas. As the land-use changes, fragmentation of the cover-types by human activities into smaller patches have contributed to increased heterogeneity and reduced landscape complexity **(Western and Gichohi 1993; Smith 1996)**. It has been shown that spatial landscape pattern can strongly influence biotic community characteristics **(Ellis et al. 1999)**, for example, vegetation composition and structure influence faunal composition and richness within any given ecosystem **(O'Neill et al. 1988)**. Therefore, the emerging more open land use systems have resulted into local and regional loss of vegetation species that could have originally existed within the former intact landscape conditions.

The ecological implications of the present landscape development within the Mbeere district are reflected by the initiation of vegetation succession processes and subsequent changes in cover type distribution, areas, and transitions from one type to another within the different land use systems. These succession processes may imply changes in the ecological contents of the different cover types. For example, expansion of crop cultivation into natural vegetation areas has led to fragmentation of those specific patches by splitting of the existing continuous ones **(Dunn et al. 1990)**.

The number of plant species decreases after opening up the forest or bushland to cultivation. This decrease in plant species numbers and covers results in decreases in the amount of soil organic carbon. Comparison of soils in uncultivated with soils in the areas with perennial crops, pasture or even in annual crops showed reduced amounts of soil organic matter. Soil carbon in the cultivated areas is lowest in the horticulture areas than in any other land use **(Maitima et al 2004)**. This is due to the high intensity of land use in horticulture farming.

6. LIVESTOCK PRODUCTION TRENDS, CHALLENGES AND OPPORTUNITIES

6.1 Livestock and crop-livestock livelihoods in Mbeere District

The fragmentation and alteration of natural habitats into large areas of croplands has eliminated the option of free range grazing. Grazing is now in secluded patches of within individual farms. The situation has increased livestock density with the areas designated as grazing lands, which has subjected these areas to heavy forage utilization. The situation has led to increased competition between livestock production and crop production. There are two scenarios of change in relations to implications on livelihood. First there is shift from being predominantly livestock keepers to mixed crop-livestock producers. The second scenario is that among the crop-livestock producers, changes in economics of production has forced many to adopt to new livestock breeds that are able to pay off for the extra cost required in the changed management systems (**Maitima et al 2004)**.

Most farmers in Mbeere are small-scale farmers and practice livestock keeping and crop cultivation. Livestock is seen by many as a bank and insurance for the farmer. Many farmers sell their surplus farm produce to buy livestock to keep. In view of the trends in changes in land use livestock production is going to grow as a means of intensifying production in the declining land sizes. The livestock sector that may grow is dairy production because it requires less land and milk is a commodity that has market.

The zebu cattle in the district are kept under extensive production system (free-range system), and are corralled at night. Cattle are grazed on the local poor quality roughage (local grass pastures) with limited opportunity for commercial supplements and protein rich feeds due to high costs. Hence cheap and practical options such as the use of protein rich forages grown at the farm are desirable. Cattle are also fed on farm byproducts such as cereal stovers (maize, sorghum, millet etc.), which are important feed sources during dry periods when other fodder types are scarce. However, these crop residues and other fodder types in the district are of varying quality according to weather conditions; and mostly the quality is low. Water for livestock production is a major constraint especially during the dry periods when most seasonal rivers, ponds and dams dry up and livestock have to be watered from the permanent rivers and dams. During the dry periods animals sometimes walk 5-20 km in search of water **(DLPO, 2005).**

On average, zebu bulls weigh 250 Kg while cows weigh 180 Kg respectively. Milk production is in the range of 1-2 litres per day per cow with a lactation period of 150 days. In general, it has been observed that cattle under smallholder systems have low fertility and long calving intervals due to inadequate nutrition.

6.2. Selected Livestock Types and Their Management

6.2.1. Cattle

4.2.1.1. Multipurpose cattle (Beef cattle)

The Small East African Zebu cattle are the most numerous and widely distributed in Mbeere District as well as other parts of Kenya. The *B. indicus* group also includes Sahiwals and the Borans and their crosses. Unlike exotic breeds, the zebu cattle are well adapted to harsh environmental conditions; poor feed supply, local diseases and climate.

Economically, the zebu cattle support majority of the rural families in Mbeere District by providing food, income and by being considered an investment. They are kept by individual households for different roles **(Box 2)**. The beef ranches that used to exist within the district have virtually collapsed and the land sub-divided.

Box 2: Roles of livestock in Mbeere District

a) Production role
- Meat, milk; subsistence and cash income when surplus is sold

b) Investment role
- Buffers investment risk when crops fail (diversification)
- Investment for old age and incapacitation; savings
- Stock to bequeath to children

c) Social-cultural role
- Number of animals and species an element of status symbol
- Social obligations: payment of dowry during marriage;
- Medium of exchange; slaughtered in social ceremonies

d) Energy role
- Draught power (ploughing; farm transport)

e) **Nutrient role**

- Provide manure; closing the carbon and nitrogen cycles.

DRSRS TO PROVIDE numbers of District Development Plans

6.2.1.2. Dairy cattle

The district has few dairy cattle, mainly crosses of Friesian, Guernsey, Ayrshire, and Jersey. Dairy cattle accounte for about 1.3% of total cattle population in the district. Thus dairy production is not a major livestock enterprise in the district. It is confined to limited pockets of the medium potential areas of the district. Reports of Dry land Applied Research and Extension Project **(DAREP, 1994)** indicate that these few dairy cattle are found in Mwea, Gachoka, Mbita, Kiritiri and Siakago among other parts of the district like Evurore Division.

The dairy cattle are kept under semi-zero grazing system. They are partly fed on nappier among other fodder types. However, due to low and short duration rainfall, nappier grass and other fodder trees often doesn't meet the dry matter requirement for growth and subsequent regeneration after cutting is negligible. Therefore, inadequate forage is one of the most limiting factors to dairy cattle production after tick borne diseases in Mbeere District **(Kangara *et al*., 1996)**. Farmers who keep dairy cattle in the district use limited amounts of concentrates in combination with other feeds due to low returns per unit cost. Milk production for the dairy cattle is in the range of 3-4 litres per day with a lactation period of 200-250 days. Milk production in the district is low and does not meet the district's demand.

6.2.3 Livestock production Constraints and Opportunities

Despite the harsh environment, there is opportunity to improve cattle production, as livestock is an important component of the farming systems in Mbeere district. A summary of constraints to cattle production and some opportunities for addressing the same are consigned in **Box 3.** These constraints we got from farmers through PRAS and stakeholders during workshops

Box 3: A summary of constraints and some opportunities for improving cattle production

Constraints

- Poor quality forage; inadequate improved pasture and fodder.
- Inadequate forage throughout the year.
- High prices for commercial feeds.
- Low-to- no level of supplementation.
- Low genetic potential of the animals (low milk production, low growth rates, long calving intervals etc.).
- Inadequate water for animals during the dry periods.
- Prevalent diseases: anaplasmosis, East Coast Fever, babesiosis, Rift valley fever heart water, trypanosomiasis, pneumonia, helminthiasis, eye infections, Foot and Mouth etc.
- Low farm gate prices fro livestock
- Prevalent parasites: ticks and worm infestation among others.
- Limited availability of A.I. services.
- Poor housing, manure and urine collection.

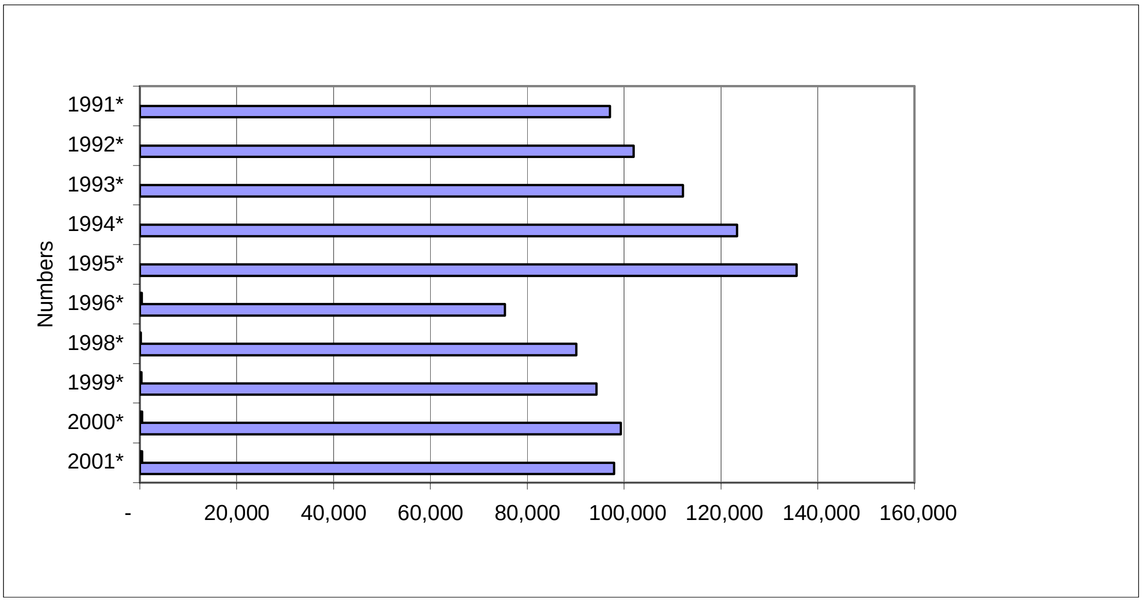
Some opportunities

- Introduction of drought tolerant fodder
- Promotion of leguminous forages e.g. Calliandra sp., Sesbania sp. etc.
- Promotion of leafy sweet potato forage.
- Skills on on-farm feed formulation and feed conservation based on local feed resources.
- Upgrading of local zebus with bulls of high genetic potential e.g. selected Sahiwals and Boran bulls.
- Promotion of bull camps and self help A.I. services.
- Promotion of community marketing groups on livestock and associated products.
- Harnessing of more water resources through community action.
- Stepping up of cattle pest and disease management by combining conventional treatments and selected ethno-veterinary practices.
- Improvement on animal housing (low cost structures) for improved manure and urine collection. Improved housing can also reduce stress emanating from mud, hot weather and small sized pens.

6.2.4 Sheep and goats (shoats)

Goat rearing is widespread in Mbeere district. Breeds of goats kept in the district are of two types: meat (Chevon) and dairy breeds. Meat goats are the most widespread. Breeds of goats found in the district include the Small East African Goat, Galla, Saanen, Toggenburg, German Alpine and their crosses. The goats are liked for their adaptability to local conditions. They have high fecundity (fertility) rate, have low feed and water requirements and have ability to walk long distances. Meat goats are the most widespread in the district **(Figure 5 and 6)**. Dairy goats comprise less than 1% of the total goat population in the district. However, the number of dairy goats is on an upward trend. On average, the dairy goats yield 2 kg milk per day per goat. Some crosses yield up to 4 kg milk per goat per day.

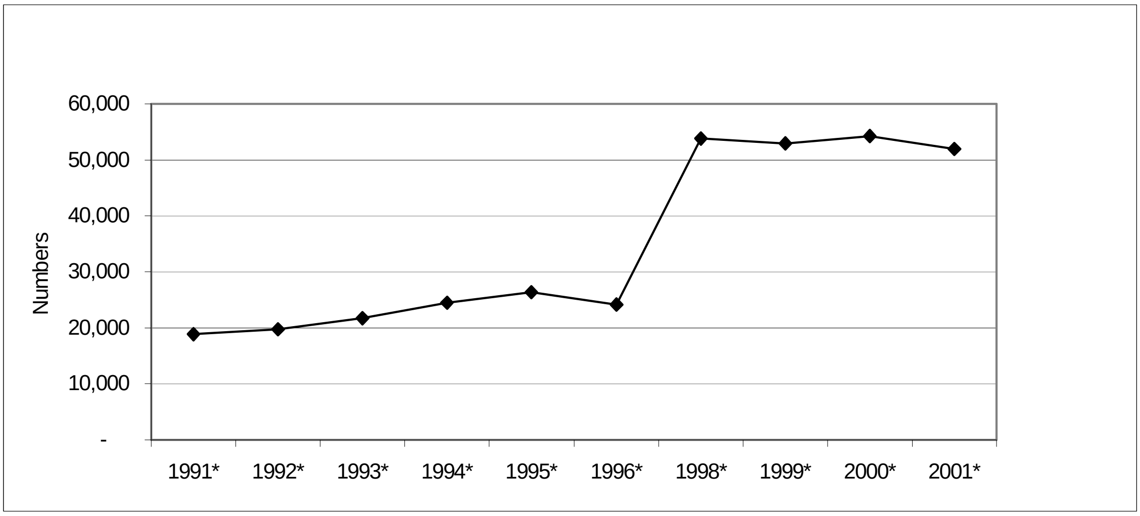
Figure 5: Goat population in Mbeere district



Source: 1991-1995 data: District Livestock Production Office, Embu (for divisions currently making Mbeere District); 1996-2001 data: District Agricultural Office, Mbeere.

Hair sheep are kept in the district for their meat (mutton) and other roles. Breeds kept include Red Maasai and Black Headed Persian, and crosses. The number of sheep in the district increased from 1991 to 1996, but has been more or less stagnating in the period 1998 to 2005.

Figure 6: Trends in sheep population in Mbeere District



Source: 1991-1995 data: District Livestock Production Office, Embu (for divisions currently making Mbeere District); 1996-2001 data: District Agricultural Office, Mbeere.

6.2.4.1 Shoats Production Constraints and Opportunities

The shoats (sheep and goats) are mainly kept under free range extensive grazing. The main constraints for shoat production in the district are similar to that those failed by cattle. The constraints include poor housing and husbandry practices, poor forage, and lack of market and poor prices. Opportunities to upgrade the local goats in the district exist through cross breeding with exotic bucks such as German Alpine. However, such bucks are not readily available, but can be acquired from neighbouring districts. A number of farmer groups have purchased these dairy bucks and nannies in the past **(DLPO, 2005)**.

6.2.5 Poultry

The main poultry type in the district is the indigenous chicken. Exotic chickens like Issa Brown and Rhode Island Red are found in limited numbers**.** Chickens have been and are still a major source of protein in the form of eggs and meat, improving the nutrition of the rural people and providing cash money to the families.

Indigenous chickens are kept under free-range system and are usually accorded poor management. Their yield potential is low. The hens lay a batch of 10-12 eggs and then become broody. They repeat this 3-4 times a year. Despite low production, rural chickens occupy a very important niche in rural households. They are locally adapted and are able to scavenge and harvest nutrients for growth, production and reproduction. They survive on little inputs and give an output. These make them suitable for rural farmers because they cope well with feed fluctuations and availability across seasons.

The population of indigenous chicken decreased from 1995 to year 2001. The fluctuation in population was partly due to sales to earn cash to buy food during periods of food shortage.

6.2.5.1 Poultry Production Constraints and Opportunities

Constraints associated with chicken production are presented in **Box 4**. It has been reported that indigenous chicken can produce more eggs with better management and thus increase farmer's earnings **(MoLD, 1989)**. **Ndegwa and Kimani, (1996)** have further reported that consumers in rural and urban areas prefer meat from indigenous chicken to commercial chicken because of taste, texture and colour.

Box 4: Constraints and Potentials of Poultry Production

Constraints

- Irregularly given water
- Disease incidences: New Castle, Coccidiosis etc.
- Pest incidences
- Poor housing
- Given less attention in terms of feeding
- Low genetic potential

Potentials

- Upgrading local chicken through exotic cockerels
- Improved record keeping to demonstrate economic feasibility of keeping chickens.
- Enhanced skills in poultry nutrition and management
- Local feed formulation for poultry

7. SOIL FERTILITY MANAGEMENT PRACTICES

7.1. Overview

Soil fertility has been declining in the semi-arid regions of Eastern Kenya including Mbeere District **(Kihanda and Warren, 1998)**. Other studies have shown that soil fertility decline is the biophysical root cause of decreasing per capita production **(Warren, *et al*., 1996)**. To reverse soil fertility decline, effective management strategies need to be explored at the levels of adding nutrients to the production system, reducing losses of nutrients already available in the system, optimizing nutrient cycling and increasing the efficiency of nutrient uptake **(Hilhorst and Muchena, 2000)**. The decline in fertility is attributed to farmers' limited knowledge base in Integrated Nutrient Management (INM). This is further exacerbated by inappropriate and, sometimes, untimely response to constraints posed by socio-economic and biophysical pressures within which soil fertility management takes place.

In Mbeere District, it has been reported that the quantities of nutrients being removed from the soil, through crop uptake, leaching and erosion exceed the amount of nutrients returned to the soil through natural processes such as atmospheric deposition and biological nitrogen fixation or through additions of inorganic and organic fertilizers. Nitrogen is being depleted at the rate of 26 to 46 kg ha^{-1} yr^{-1} **(Gitari *et al*., 1999; Kihanda and Gichuru, 1999)**. Other authors working in semi-arid areas (**Karyotis *et al* 2005)** of Kenya have also shown that current farm management practices results in nitrogen depletion at the rate of 53 to 56 kg ha^{-1} yr^{-1}, implying that 60-80% of farm income is based on nutrient mining **(De Jager *et al*., 1999)**. In general, the soils in Mbeere District are reported to have low organic matter, nitrogen and phosphorus contents except for localized areas.

Another soil productivity constraint in Mbeere District is the limited available soil moisture **(Devuskog, 2001)**. However, **Kiome (1997)** has reported that the notion that water is the most limiting agricultural production factor in semi-arid areas of Kenya is in contradiction to previous work in these areas, which have shown that without soil fertility improvement, water management does not produce significant benefits.

7.2. Major practices, constraints and possibilities

7.2.1. Fallowing

In the past (1920s-1930s) arable farming was practiced through long fallow periods in the low potential areas of Kenya especially under shifting cultivation methods coupled with "slash and burn" practices before the onset of tillage. **Giller *et al*., (1997)** have reported that the long fallow periods restore soil fertility through reduced mineralization rates in the absence of tillage, deposition from the atmosphere (nitrogen), deep root nutrient capture, nitrogen inputs through recalcitrant organic matter, decomposition of crop residues and contribution made from free-living or root associated nitrogen fixation in the presence of carbon-rich substrates. However, in the face of rising population pressure and subsequent division of land, the fallow periods have reduced tremendously and can no longer restore soil fertility. Thus there is a need for other options for enhancing and restoring soil fertility.

7.2.2. Crop residues

The availability of crop residues as a source of organic material for the maintenance of soil fertility is a reflection of farming system practices. In the semi-arid areas of Mbeere, crop residues are generated mainly from cereals and pulses. Residues from banana, mangoes and other fruit trees in the form of litter fall or otherwise are also of local importance. Maize and beans residues are mainly used for livestock feeding especially during the dry season or after harvest. They are grazed as standing stalks or preserved for cattle feeding in the dry season.

The cereals and pulses residues are rarely incorporated into the soil or used as surface mulch. Some of the dry maize stovers are used as fuel. The kitchen ash generated from burning of the residues is sometimes returned to the soil together with other kitchen remains.

7.2.3. Mulching practices

Mulching practices are not common in Mbeere District and are not extensively practiced in the general field. Where it is practiced (high value crops), various forms of plant residues are used as mulch including dry grass and crop residues.

7.2.4. Green manuring

Green manuring practices are not widely used in Mbeere District as in many parts of sub-Saharan Africa. Constraints in the adoption of green manuring includes the fact that the “crop” is perceived by farmers not to bring cash returns and farmers, in most cases, lack the relevant information on opportunities in using green manuring and or technology for incorporating it into the soil. In some cases, farmers consider that land is too limited to be used for non-food crops, and in some cases, availability of green manuring is limiting **(Ofori, 1980).**

7.2.5. Use of legumes

The role of legumes in improving soil fertility is well recognized by the scientific community. The integration of tree legumes into the farming systems is slowly being accepted in Mbeere, but has not been extensively adopted. However, Mbeere District, grain legumes like cowpeas, field beans, pigeon peas and other short-term legumes are being grown in mixed cropping systems with cereals like maize.

7.2.6. Soil and water conservation practices

Soil fertility management cannot be effective without accompanying practices for preventing the loss of nutrients stored in the topsoil through soil erosion **(Gachimbi *et al* 2002)**. In Mbeere various soil and water conservation practices have been adopted to conserve the fragile soils. Such practices include terracing, trash lines, use of organic inputs (manure, compost, crop residues etc.), mulching, stone lines and cover cropping.

7.2.7. The use of manure and compost

Manure is the commonly used and readily available soil amendment in Mbeere District. The use of manure to improve crop productivity provides an avenue for the resource poor farmers to improve crop and soil productivity. However, compost production is not widely practiced.

Manure use in Mbeere has not only been constrained by its availability, but also its quality. In the semi-arid areas of Eastern Kenya, **Probert *et al*., (1990) and Ikombo (1984)** have reported that on-farm manure availability (faecal dry matter) is in the range of 0.98 to 1.53 tones ha^{-1} yr^{-1}. This is not enough to fertilize whole farms in a single cropping season. Thus increasing manure availability at farm level still remains a challenge. However, farmers have been applying manure in a rotational basis, creating hot spots in various parts of the farm over the years. Manure applications of 5-8 tons ha^{-1} have been reported to be adequate in meeting cereal crop requirements in the semi arid areas of Mbeere, Tharaka and Machakos Districts **(Ikombo, 1984; Gibberd, 1995)**. The residual effects of 5, 8 and 10 tonnes ha^{-1} manure were found to be similar (three years data), in the semi-arid areas of Eastern Kenya and that applying small quantities of manure frequently gave better cereal yields (maize and sorghum) than applying large doses at long time intervals **(Ikombo, 1984; Kihanda and Warren, 1998)**. **Gatheca (1970)** reported that annual applications of 5 to 6 tonnes ha^{-1} of manure gave higher yields of maize and potato than heavy applications of 20 to 30 tonnes ha^{-1} manure applied at intervals of four or five years. These findings are in contrast to reports of **Kanyanjua *et al* (2000)**, who reported that there was no advantage in applying small quantities of manure frequently compared to applying large doses less frequently.

Livestock manure found in Mbeere District is of variable and low quality as it falls below the critical nitrogen content of 1.8-2% and thus, may immobilize nitrogen temporarily **(Palm *et al.*, 1997)**. Reported manure nutrient ranges in the semi-arid areas of Kenya are 0.2% -1.62%N, 0.10%-0.5% P and 0.28%-1.34%K (**Probert *et al*., 1990; Diop et al., 1997; Ikombo (1984).** Factors influencing manure quality in include quality of feeds, animal size and age in addition to poor methods of manure and urine collection, storage and application **(Somda *et al*., 1995; Nzuma and Murwira, 2000)**.

The beneficial effects of manure on soil biophysical and chemical conditions have been widely published. Manure improves soil biophysical and chemical conditions through acting as a precursor to soil organic matter, adding nutrients to the soil, providing carbon (the source of energy for soil biota that regulates nutrient cycling), influencing mineralization-immobilization patterns and reduces soil phosphorus sorption of the soil **(Sanchez *et al*., 1997; Palm *et al*., 1997)**. **Muller-Samann and Kotschi (1994)** have reported that the use of manures improves soil structure. Similarly, **Arakeri *et al* (1962), Dalzell *et al*. (1979) and Flaig (1975)** have reported that addition of manure increases the biological activity of the soil, improves water holding capacity and crumb formation, improves infiltration, protects the soil against erosion and facilitates the spread and penetration of plant roots. **Tamaka (1974)** reported that trace elements, which often develop after several years of mineral fertilizer application, are less likely to occur when manure and compost are used. Manure moderates soil temperatures and its continued use can progressively improve soil cation exchange capacity, exchangeable bases and smoothen soil pH **(Grant, 1967)**. In the semi-arid areas of Eastern Kenya, **Kihanda and Warren (1998)** found that the addition of manure always caused highly significant increases in Olsen P, the increase being proportional to the rate of manure applied.

7.2.8. Use of mineral fertilizers

The use of inorganic fertilizers to improve soil fertility and crop productivity in Mbeere District is very low. For example, farmers who use inorganic nitrogen fertilizers do so at rates between 3 kg N ha^{-1}, instead of the recommended rates of 50 kg N ha^{-1} **(Maize Data Base, 1993, Kanyanjwa and Ayaga 2006).**

A wide range of factors has militated against the use of mineral fertilizers in smallholder farms **(Nandwa and Bekunda, 1998**). Such factors include (i) highly variable responses to fertilizer use under smallholder conditions, which make the technology risky and difficult to adopt by the resource-poor farmers, (ii) efficiency of mineral fertilizer use is often low (<30%), which is attributed to use on soils with low organic matter (carbon) and nutrient imbalances resulting from past farming practices (iii) lack of farmers knowledge on appropriate Integrated Soil Fertility Management Practices (ISM) and (iv) limited financial means coupled with absence of rural credit. The removal of subsidies and liberalization of fertilizer sector under structural adjustment programmes in the last decade has also resulted in increased fertilizer prices, putting them beyond the reach of many smallholder and resource limited farmers.

7.2.9. Other cultural practices

Timing of seeding is a traditional technical knowledge practiced in semi-arid areas of Kenya. The common practice with the farmers is to plant with the first rains especially in Mbeere where rainfall is unpredictable and unreliable. Appropriate timing of the first rains help in capturing the nitrogen flush released during the fast decomposition of organic materials by soil organisms at the onset of rains after the dry spell. Besides, timing of planting, crop rotation is also widely practiced, although the crop sequence may not, in some cases, be geared towards maintaining soil fertility.

7.3.0 Opportunities for improving soil fertility

A summary of soil fertility management constraints in Mbeere District is presented in **Box 5.** The low quality of manure and compost in Mbeere District can be addressed by minimising nutrient losses before application. This implies developing strategies for improving manure collection, storage and handling. The use of crop residues recycled as bedding materials in cattle kraals, use of pit storage methods, covering the kraals, covering manure and compost during decomposition and making use of additives during decomposition process (e.g. rock phosphates, wood ash etc.) are strategies that may need to be further explored in the quest for improved soil fertility management in the district.

Box 5: Summary of soil fertility management constraints in Mbeere District

- Use of reduced fallow periods, which can no longer restore soil fertility.
- Low quality of crop residues; inadequate recycling.
- Low levels of using green manuring and mulching practices.
- Low levels of integrating tree and herbaceous legumes.
- Inadequate availability of manure and compost at farm level; low quality of manure and compost.
- Inadequate or none use of mineral fertilisers and other external soil fertility inputs.
- Inadequate adoption of methods for increasing soil moisture retention and reducing nutrient losses (water harvesting and soil and water conservation practices).
- Farmers limited knowledge on integrated soil productivity improvement.

Limited amounts or no mineral fertilisers are used for food crop production due to escalating costs. To off set this constraint, there is need for exploring the use of less costly materials like rock phosphates. However, rock phosphates (low reactive) have been demonstrated to be working well, only, under soil acidic conditions, when partially acidulated or when compacted with water soluble P fertilisers, such as TSP **(Buresh et al., 1997)**.

In the study sites, possibilities to improve soil fertility through the use of crop residues, rotations and legumes, and green manures need to be further explored to progressively off set constraints to their use. Applications of residues with high C:N ratio to soils can lead to short-term N deficiencies due to N immobilization. Composting the crop residues or feeding them to animals help in improving their quality as soil amendments. The use of legumes as intercrops, in rotations or under relay cropping can contribute to offsetting nitrogen deficiencies under appropriate management. **Sanchez *et al*., (1997)** have reported that the use of leguminous fallows grown during the dry season or when crops are not in the field can accumulate 100-200 kg nitrogen ha^{-1} through biological nitrogen fixation or deep root capture. **Giller *et al*., (1997)** have also reported that relay cropping with pigeon peas may capture free nitrate-Nitrogen from deep horizons. The use of green manures in the study site will depend on intensified efforts in educating farmers on the opportunities of using them and on methods and availability of seeds for suitable green manure plants.

In Mbeere District, technologies that conserve nutrients and prevent their loss are crucial for improving and maintaining soil fertility. Furthermore, in the semi-arid areas, techniques that improve soil moisture content, such as water harvesting and soil and water conservation technologies are crucial to production.

Wildlife options missing

Other Priority Problems, Causes, Copping Mechanisms and Opportunities as Detailed in Development Plans or Workshop report

8. DISCUSSIONS AND CONCLUSIONS

The review has shown that rainfall variability and amounts of rainfall received are two main hindrances in the pathway to developing productive farming systems in agropastoral farming systems. Furthermore, land degradation through soil erosion is evident in many parts of the District. While increasing water availability to crops through irrigation is constrained by inadequate cash capital to harness the water resources in the District, a possible supplementary option is to intensify efforts on soil and water conservation practices and to explore options for synergy through judicious water harvesting practices. This can be done through the Farmer Field School (FFS) approach, which equips farmers with field management skills and empowers them to implement their own decisions in their own farms based on sound understanding of principles and practices of a wide-range of options and technologies. These technologies essentially need to include soil moisture retention technologies as well as water harvesting practices.

It is clear that the yields of major food crops (cereals, legumes and root crops) in Mbeere District have been fluctuating with a general trend of either declining or stagnating in the last one decade. Increasing food production in the agropastoral communities will require re-addressing the limiting livestock and crop production constraints including factors responsible for soil nutrient depletion among other variables. Factors to consider in crop production include soil fertility, competition from pests (insects, diseases, weeds), management (timing of operations, plant density, etc) and genetic characteristics (maturity period, uniformity, plant architecture and pest resistance). The realignment of research to address these production constraints will require a strategy for an additive adoption sequence, which will gradually move farmers towards the utilization of better production practices.

The study has shown that constraints to livestock production in Mbeere District include feed supply, animal health, low genetic potential and livestock management. There is general inability to produce adequate and quality livestock feed throughout the year resulting in low intake of digestible nutrients (proteins, energy and minerals) and weight loss especially in the dry season. Off setting these constraints may require the adoption and promotion of strategic methods of on-farm supplementation of animal diets, proper methods of conservation of forages or harvesting and storage of forage at the time of maximum nutrient content.

The study has also shown that farmers in Mbeere District employ a wide variety of soil fertility management technologies and practices to reverse land degradation and that soil fertility management is dominated by traditional practices such as the use of organic inputs with or without limited additions of mineral fertilizers. However, the current rates, methods and timing of application of these nutrient sources offer limited potential for improved soil fertility management.

It can be concluded that there is no single remedy for improving soil fertility in semi-arid areas of Mbeere District. Maximising internal nutrient sources while optimising the use of low cost external inputs within the framework of integrated nutrient management would be a plausible way forward. However, this requires conscious, demand driven and judicious investment in the biophysical, institutional and socio-economic environment within which soil fertility management takes place.

9. REFERENCE

Alexandratos, N., 1995. The outlook for world food and agriculture to year 2010. In: Islam, N. (Ed.) Population and food in the early twenty-first century: Meeting future food demand of an increasing population. IFPRI, Washington DC, USA.

Anon, 1981. The sessional Paper No. 4. National Food Policy, Government of Kenya, Nairobi.

Anyango, J.J., Odhiambo, B. and Songa, J., 1999. Changes in pest and disease status on cowpea in Eastern Province of Kenya. In: Sutherland, J.A (Ed.), Towards increased use of demand driven technology, end of project conference, 23rd-26th March 1999, KARI and DFID, Nairobi, pp 144-146.

Arakeri, H.R., Chalam, G.V., Satyaranayana, P. and Donahue, R.L., (Eds.) 1962. Soil management in India. Bombay. 619 pp

Badiane, O. Delgado, C.L., 1995. A 2020 vision for food, agriculture and the environment in sub-Saharan Africa. Food, Agriculture and the Environment. Discussion paper 4. International Food Policy Research Institute. Washington, DC.

Buresh, R.J., Smithson, P.C. and Hellums, D., 1997. Building soil phosphorus in Africa. In: Buresh, R.J., Sanchez, P.A. and Calhoun, F. (Eds.). Replenishing soil fertility in Africa. SSA N0. 51. ICRAF.

Cappock, D.L. and Reed, J.D., 1992. Cultivated and native browse legumes as calf supplements in Ethiopia. Journal of Range Management 45 (3): 231-238.

Central Bureau of Statistics (CBS), 2001. 1999 Population and Housing Census. II. Socio-econmoc profile of the population. Ministry of Finance and Planning, Republic of Kenya. Central Bureau of Statistics.

Central Bureau of Statistics (CBS), 2001. The 1999 Population and Housing Census. Vol. I. Ministry of Finance and Planning, Republic of Kenya.

DLPO, 2005. Livestock production annual report for the year 2005. District Agriculture and Livestock Extension Office, Mbeere. Ministry of Agriculture and Rural Development.

Dalzell, H.W., Gray, K.R. and Biddlestone, A.J., 1979. Composting in tropical agriculture. The international Institute of Biological Husbandry. Review papers No. 2, Ipswich,

DAREP, 1994. Informal diagnostic survey of Tharaka-Nithi. Dryland Applied Research and Extension project. KARI, Regional Research Centre, Embu.

DAREP, 1995. Report on informal diagnostic survey of farming systems in Tharaka Nithi informal diagnostic survey of Tharaka North and Central Divisions of Tharaka-Nithi district, Kenya. Dryland Applied Research and Extension Project. KARI, Regional Research Centre, Embu.

De Jager, A., Onduru, D.D., Wijk, M. S., Vlaming, J. and G.N. Gachini. 1999. Assessing potentials of Low External Input farm technologies with the nutrient monitoring approach: A case study in Kenya. Agricultural Systems 69: 99-118.

Diop, JM., Onduru, D.D., Werf van der., Kariuki, J., 1997. On-farm Agro-economic Comparison of Organic and Conventional Techniques in Medium and High potential Areas of Kenya. KIOF/ETC-Netherlands.

D'Mello, J.P.F., 1992. Chemical constraints to the use of tropical legumes in animal nutrition. Anim. Feed Sci. Technol. 38: 237-261.

Duveskog, D., 2001. A study guide for farmer field schools. Water harvesting and soil moisture retention. FARMESA GCP/RAF/334/SWE.

Ellis, J., Reid, R., Thornton, P. and Kruska, R. 1999. Population growth and land-use change among pastoral people: local processes and continental patterns. In People and Rangelands, Building the Future. Proceedings of the VIth International Rangeland Congress. Edited by David, E. and David, F.Townsville, Queensland, Australia. Vol. 1: 168-169.

Elwell, P.T., 1990. Sweet potato in Eastern and Southern Africa. Paper presented at the Workshop on the sweet potato food systems of Eastern and Southern Africa, Nairobi, Kenya.

FAO, 1984. Year book, 1984. Food and Agriculture Organization of the United Nations.

FAO, 1986. African agriculture: The next 25 years. Annex 4, Irrigation and water control. FAO, Rome.

FAO, 2001. Soil fertility management in support of food security in sub-Saharan Africa. Food and Agriculture Organizations of the United Nations, Rome.

Flaig, W., 1975. Specific effects of soil organic matter on the potential of soil productivity, FAO soils Bulletin No. 27, Rome, pp. 31-70.

Gachimbi, L.N., de Jager, A., van Keulen, H., Thuranira, E.G., Nandwa, S.M. 2002. Participatory diagnosis of soil nutrient depletion in semi-arid areas of Kenya. Managing Africa's soils No. 26. International Institute for Environment and Development, London, UK.

Gachimbi, L.N, Itabari, J.K., Karuku, A.M., Van Keulen, H, De Jager, A., Maina, F.W, Thuranira EG. 2006. Development of Integrated management systems in semi-arid areas of Kenya. Kenya Agricultural Research Institute. *KARI Technical Note No.14, January 2006*

Gachimbi, L.N., H, van Keulen., Thuranira, E.G., A.M. Karuku., De Jager, A., Nguluu, S.N., B.M., Ikombo., J.M, Kinama., J.K. Itabari and S.N. Nandwa. 2004. Nutrient balances at farm level in Machakos (Kenya) using a participatory nutrient monitoring (NUTMON) approach, *Land use policy. 22: 13-22 Elsevier.*

Jager de. A., H. Van Keulen, F. Maina, **L.N. Gachimbi**., J.K. Itabari, E. G. Thuranira and A.M. Karuku. 2005. Attaining sustainable farm management systems in semi-arid areas in Kenya. A few technical options, many policy challenges Agricultural systems. *International journal of Agricultural Sustainability Vol. 3. (3) 189-205.*

Gatheca, T.W., 1970. The maintenance and improvement of soil fertility under arable crops and grass lies in the first and second rotational cycle of a fertilizer trial in Embu. East Africa Agricultural and Forestry Journal 35: 246-252.

Gibberd, V., 1995. Yield responses of food crops to animal manure in semi-arid Kenya. Tropical Science 35: 418-426.

Giller, K., Cadisch, G., Ehaliotis, C. and Adams, E., 1997. Building Soil nitrogen capaital in Africa. In: Buresh, R.J., Sanchez, P.A. and Calhoun, F. (Eds.). Replenishing soil fertility in Africa. SSA N0. 51. ICRAF

Gitari, J.N. Matiri, F.M., Kariuki, I.W., Muriithi, C.W., Gachanja, S.P., 1999. Nutrient and Cash flow monitoring in farming systems on the Eastern Slopes of Mount Kenya. Nutrient Disequilibria in Agroecosystems, pp 211-227.

Gitari, J.N., Kanampiu, F.K. and Murithi, F.M., 1996. Maize yield gap analysis for mid altitude areas of Eastern and Central Kenya region. In: Fungoh, P.O and Mbadi, G.C.O., Focus on Agricultural Research for sustainable development in a changing Economic Environment. Proceedings of the 5th KARI Scientific Conference, 14th -16th October 1996. KARI, pp 216-225.

Grant, P.M., 1967. The fertility of sandveld soil under continous cultivation. Part I. The effect of manure and nitrogen on fertilizers on the nitrogen status of the soil. Rhod. Zambia Malawi Journal of Agricultural Research 5: 71-79.

Hassan, R. and Karanja, D., 1995. The role of improved seed, fertilizer and extension in transforming maize production in Kenya. Draft paper.

Hilhorst, T. and Muchena, F.M (Eds.) 2000. Nutrients on the move-Soil fertility dynamics in African farming systems. International Institute for Environment and Development (IIED), London, UK.

Ikombo, B.M., 1984. Effect of farmyard manure and fertilizers on maize in semi-arid areas of Eastern Kenya. East African Agriculture and Forestry Journal, Special Issue: 266-273.

Jager de. A., H. Van Keulen, F. Maina, L.N. Gachimbi., J.K. Itabari, E. G. Thuranira and A.M. Karuku. 2005. Attaining sustainable farm management systems in semi-arid areas in Kenya. A few technical options, many policy challenges Agricultural systems. *International journal of Agricultural Sustainability Vol. 3. (3) 189-205.*

Jager de A., H. Van Keulen, F. Maina, L.N. Gachimbi., J.K. Itabari, E. G. Thuranira and A.M. Karuku. 2005. Attaining sustainable farm management systems in semi-arid areas in Kenya. A few technical options, many policy challenges Agricultural systems. *International journal of Agricultural Sustainability Vol. 3. (3) 189-205*.

Jaetzold, R. and Schimidt, H., 1982. Farm management handbook of Kenya. Volume II. Natural conditions and farm management information. Ministry of Agriculture, Kenya.

Kangara, J.N.N., Kariuki, I.W., Mbaka, J., Muthanga, G.W., 1996. Forage production of different varieties of Kenaf in marginal and low potential areas. In: Fungoh, P.O and Mbadi, G.C.O., Focus on Agricultural Research for sustainable development in a changing Economic Environment. Proceedings of the 5th KARI Scientific Conference, 14th -16th October 1996. KARI, pp 528-532.

Karyotis, T., D. Onduru C. Noulas, L.N. Gachimbi and F.N. Muchena, September 2005. Nutrients, trace elements and Net N mineralization in Acid Soils. *Soil Sc. Plant Nutr. 51 (5): 645-648*

Kanguha, E.M. and Mailu, A., 1996. Development of medium for the rapid multiplication of cassava genotypes in Kenya. In: Fungoh, P.O and Mbadi, G.C.O., Focus on Agricultural Research for sustainable development in a changing Economic Environment. Proceedings of the 5th KARI Scientific Conference, 14th -16th October 1996. KARI, pp 76-81.

Kanyanjua, S.M., Mureithi, J.G., Gachene, C.K.K. and Saha, H.M., 2000. Soil fertility management handbook for extension staff and farmers in Kenya. Kenya Agricultural Research Institute, Nairobi, pp 24.

KARI, 1994. Strategic plan for cereals in Kenya (1993-2013). Kenya Agricultural Research Institute, Nairobi, pp 8.

Karyotis et al 2005.

Kassam, A.H., Velthuizen, H.T., Fischer, G.W. and Shah, M.M., 1991. Agro-ecological land resources assessment for agricultural development planning. A case study of Kenya. Resources database and land productivity, Technical

Annex 1, land resources, Land and Water development Division, FAO and IIASA.

Kihanda, F.M. and Gichuru, M., 1999. Manure management for soil fertility improvement. KARI and TSBF, Nairobi.

Kihanda, F.M. and Warren, G.P. (Eds.), 1998. Maintenance of soil fertility and organic matter in dryland areas. Department of Soil Science, The University of Reading, occasional publication Number 3. Proceedings of a workshop held in Embu, Kenya, Nov 27-28, 1997.

Kiome, R.M., 1997. Opening address. In: Kihanda, F.M. and Warren, G.P. (Eds.), Maintenance of soil fertility and organic matter in dryland areas. Department of Soil Science, The University of Reading, Occasional paper Number 3. Proceedings of a workshop held in Embu, Kenya, Nov 27-28, 1997.

Kneating, B.A., Wafula, B.M. and Watiki, J.M., 1990. Development of a modeling capability for maize in Kenya. In: Probert, M.E. (Ed). A search for strategies for sustainable dryland cropping in Semi-Arid Eastern Kenya. Proceedings of a symposium held in Nairobi, Kenya, 10-11 December 1990. ACIAR proceedings No 41, 138p.

Konijn, N.T., 1988. The effects on maize yields. In: Parry, M.L., Carter, T.R and Konijn, N.T. (eds.) The impacts of climatic variations on agriculture. Vol. 2: Assessments in Semi-arid Regions, pp 191-202, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Lusweti, C.M., Nkonge, C., Nandasaba, J., Wanjekeche, E., Lobeta, T and Rees, D.J., 1999. On-farm evaluation of promising sweet potato in the NARC Kitale mandate region. In: Sutherland, J.A (Ed.), Towards increased use of demand driven technology, end of project conference, 23rd-26th March 1999, KARI and DFID, Nairobi, pp 261-203.

Maitima, Joseph M., Simon M. Mbugua, Fred Atieno, and Stephen Mathai. 2004 Impacts of Land Use on Vegetation Species Composition, Distribution, Structure and Diversity: The Case of Embu and Mbeere Districts, Kenya. Land Use Change Impacts and Dynamics (LUCID) Project Working Paper 32. Nairobi, Kenya: International Livestock Research Institute

Maize Database Project (MDB), 1993. Preliminary results for the Embu area presented in a workshop held in Nairobi, Kenya, 23-24, September 1993.

MALD&M, 1993. Annual report. Department of Livestock production, Ministry of Agriculture, Livestock Development and Marketing, Republic of Kenya.

Mason, I.L., 1988. A world dictionary of livestock breeds, types and varieties, 3rd edition. CAB International, Willingford, UK.

Matiri, F.M., Ouma, J.O and Gitari, J.N., 1999. Assessment of adoption of improved crop varieties in the drylands of Eastern Kenya- a case study of Tharaka District and Mbeere Districts. In: Sutherland, J.A (Ed.), Towards increased use of demand driven technology, end of project conference, 23rd-26th March 1999, KARI and DFID, Nairobi.

Micheni, A.N. and Gathama, S.K., 1999. Farmers participation in determining the adoption of maie in Central and Eastern Highlands of Kenya. In: Sutherland, J.A (Ed.), Towards increased use of demand driven technology, end of project conference, 23rd-26th March 1999, KARI and DFID, Nairobi.

Miruka, M., 1999. Increased cash and food security through improved storage methods for fresh sweet potato in SouthWest Kenya. In: Sutherland, J.A (Ed.), Towards increased use of demand driven technology, end of project conference, 23rd-26th March 1999, KARI and DFID, Nairobi.

MoLD, 1989. Poultry production manual. Ministry of Livestock Development, Republic of Kenya.

MoPND, 1997. Mbeere District Development Plan, 1997-2001. Office of the Vice President and Ministry of Planning and National Development, Republic of Kenya. Government Printer, Nairobi, Kenya.

Müller-Sämann, K.M. and Kotschi, J., 1994. Sustaining growth - soil fertility management in tropical smallholdings. CTA - GTZ, Margraf Verlag, Weikersheim, Germany, 486 pp.

Mureithi, J.G., 1992. Alley cropping with leucaena and fodder production in smallholder farms in coastal lowlands of Kenya. PhD Thesis, University of Reading.

Muruli, B.I., Pathak, R.S., Mukunya, D.M., Karel, A.K., Keya, S.O and Ssali, H., 1980. Cowpea research in Kenya. Tropical Grain Legume Bulletin, 19:13-16

Muthamia, J.G.N and Kanampiu, F.K., 1996. On-farm cowpea evaluation in the marginal areas of Eastern Kenya.

Muthamia, J.G.N., Ngungi, J.N., Mwangi, M.M. and Karioko, L., 1999. Improving household food security in the dryland areas of Eastern Kenya- Traditional methods of preserving sweet potatoe planting materials. In: Sutherland, J.A (Ed.), Towards increased use of demand driven technology, end of project conference, 23rd-26th March 1999, KARI and DFID, Nairobi.

Nandwa, S.M. and Bekunda, M.A., 1998. Research on nutrient flows and balances in East and Southern Africa: State-of-the art. Agriculture Ecosystems and Environment 71:5-18.

Ndegwa, A.M., Muthamia, J, Omunyin, M, Okoko, A.O, Mbugua, G. and Muriuki, J., 1990. Bean production survey in Kisii, Muranga and Meru Districts of Kenya. National Horticultural Research Centre, Thika.

Ndegwa, J.M. and Kimani, C.W., 1996. Rural poultry production in Kenya: Research and development strategies. In: Fungoh, P.O and Mbadi, G.C.O., Focus on Agricultural Research for sustainable development in a changing Economic Environment. Proceedings of the 5th KARI Scientific Conference, 14th -16th October 1996. KARI, pp 511-516.

Ngoroi, E.H., Gitari, J.N., Karumba, S.K., Munyiri, P., 1999. Reducing risk for small holder farmers in the dryland areas of Eastern Kenya-improved varieties of pearl millet and sorghum. In: Sutherland, J.A (Ed.), Towards increased use of demand driven technology, end of project conference, 23rd-26th March 1999, KARI and DFID, Nairobi, pp 200-204.

Nkonge, C., Kwambai, T., Lusweti, C.M., Wanjekeche, E., Lobeta, T. and Osore, P., 1999. Participatory evaluation of cassava varieties for increased production and cash generation in North West Kenya.

Nzuma, J.K. and Murwira, H.K., 2000. Improving the management of manure in Zimbabwe. Managing Africa's soils No 15, International Institute for Environment and Development, Drylands programme, London.

Ofori, C.S., 1980. The use of organic materials in increasing crop production in Africa. Paper 7. In: FAO, Organic recycling in Africa. Papers presented at the FAO/SIDA workshop on the use of organic materials as fertilisers in Africa held in Bue, Camerron, 5-14th Dec 1977. FAO soils bulletin No. 43, Rome.

Ogecha, J.O., 1995. A review of sorghums and millet production constraints in South Western Kenya. Paper presented at a workshop on a review of agricultural practices and constraints in Southwest Kenya, October 1995.

Okeyo, A.M., Mosi, R.O., Ahuya, C.O., Rege, J.R.O. and Okomo, M.A., 1996. Phenotype characteristics of the Small East African zebu cattle in the Lake Victoria Basin and Coastal Lowlands of Kenya: morphological and physical characteristics. In: Fungoh, P.O and Mbadi, G.C.O., Focus on Agricultural Research for sustainable development in a changing Economic Environment. Proceedings of the 5th KARI Scientific Conference, 14th -16th October 1996. KARI, pp 252-269.

Okoko, O and Makini, F., 1999. On-farm evaluation of beans cultivars in the farming systems of South West Kenya. In: Sutherland, J.A (Ed.), Towards increased use of demand driven technology, end of project conference, 23rd-26th March 1999, KARI and DFID, Nairobi.

Onduru, D.D., Njoroge, W., Muchena, F., De Jager, A., Nandwa, S., 2000. Soil Fertility Management: Practices and technologies, A guide for extension workers. KIOF, Nairobi.

Onyango, J.W. and Muriuki, A.W., 1996. Highlights of uses of agroclimatology in fertilizer research on maize in smallholder farms in Kenya. Proceedings of the 5th KARI Scientific Conference, "Focus on Agricultural Research for Sustainable Development in a changing Economic Environment", 14th-16th October 1996. KARI, BDDEA, SIDA, USAID and CIP, Nairobi, pp 138-148.

Palm, C.A., Myers, R.J.K., and Nandwa, S.M., 1997. Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment. In: Buresh, R.J., Sanchez, P.A. and Calhoun, F. (Eds.). Replenishing soil fertility in Africa. SSA No. 51. ICRAF.

Pretty, J.N., Thompson, J and Hinchchliffe, F., 1996. Sustainable Agriculture: Impacts on food production and challenges for food security. Gatekeeper Series No. 60. IIED, London.

Probert M .E., Okalebo J. R., Simpson J.R and Jones R. K., 1990. The role of boma manure for improving soil fertility. In Probert (eds). Asearch for strategies for sustainable dryland cropping in semi-arid Eastern Kenya. ACIAR proceedings No. 41. ACIAR.

Sanchez, P.A., Shephered, K.D., Soule, M.J., Place, F.M., Buresh, R.J. and Izac, N. A-M. Mokwunyu, A.U., Kwesiga, F.R., Ndiritu, C.G. and Woomer, P.L., 1997. Soil fertility Replenishment in Africa: An Investment in Natural Resource Capital. In: Buresh, R.J., Sanchez, P.A. and Calhoun, F. (Eds.). Replenishing soil fertility in Africa. SSA No. 51. ICRAF.

Sketchley, H.R., Mbuvi, J.P., Wokabi, S.M. and Scilley, F.M., 1978.Reconnaisance Soil Survey of portions of the Machakos-Kitui-Embu Area, Scale 1: 250,000. Kenya Soil Survey, National Agricultural Research Laboratories, Ministry of Agriculture, Kenya.

Sombroek, W.G., Braun, H.M.H and van der Pouw, B.J.A., 1982. Exploratory Soil Map and Agro-climatic zone map of Kenya, scale 1: 1,000,000. Kenya Soil Survey, National Agricultural research Laboratories, Ministry of Agriculture, Kenya.

Somda, Z.C., Powell, J.M., Fernande-Rivera, and Reed, J. 1995. Feed factors affecting nutrient excretion by ruminants and the fate of nutrients when applied to soil. In: Powell, J.M et al., (Eds.), Livestock and sustainable nutrient recycling in mixed farming systems of sub-Saharan Africa. International Livestock Centre for Africa, Addis Ababa, Ethiopia.

Songa, J.M., Songa, W., Kavoi, J and Kimotho, L., 1999. Integrated management of the bean maggot in small-scale bean farms in semi-arid Eastern Kenya. In: Sutherland, J.A (Ed.), Towards increased use of demand driven technology, end of project conference, 23rd-26th March 1999, KARI and DFID, Nairobi.

Sutherland, J.A., Ouma, J.O. and Ndubi, J., 1994. Lower Embu diagnostic survey. Study report No. 5.

Tamaka, A., 1974. Methods of handling cereal crop residues in Asian Countries and related problems. In: Extension Bulletin, No. 43. ASPAC. 29 pp.

Tiffen, M., Mortimore, M. and Gichuki, F., 1994. More people less erosion. Environmental Recovery in Kenya. ACTS, Nairobi, Kenya and ODI, London.
Van de Weg, R.F. and Mbuvi, J.P., 1975. Soils of the Kindaruma Area, Scale 1: 100,000.

Wachira, M.M., 1996. The influence of weather parameters on bean yields at Katumani in Machakos District. In: Fungoh, P.O and Mbadi, G.C.O., Focus on Agricultural Research for sustainable development in a changing Economic Environment. Proceedings of the 5th KARI Scientific Conference, 14th -16th October 1996. KARI.

Wanyama, J.M., Njue, E.K. and Kidula, N.L., 1996. Evaluation of sorghum technology adoption levels in Homa Bay district. In: Fungoh, P.O and Mbadi, G.C.O., Focus on Agricultural Research for sustainable development in a changing Economic Environment. Proceedings of the 5th KARI Scientific Conference, 14th -16th October 1996. KARI, pp 360-369.

Warren, G.P., Muthamia, J. and Irungu, J.W., 1996. Soil fertility improvements under manuring in semi-arid lower Embu and Tharaka-Nithi. In: Fungoh, P.O and Mbadi, G.C.O., Focus on Agricultural Research for sustainable development in a changing Economic Environment. Proceedings of the 5th KARI Scientific Conference, 14th -16th October 1996. KARI, pp 151-163.

Western, D. and Gichohi, H. 1993. Segregation effects and the impoverishment of savannah parks. The case for ecosystem viability analysis. African Journal of Ecology 31: 268-271