This paper was peer-reviewed for scientific content.
Pages 139-146. In: D.E. Stott, R.H. Mohtar and G.C. Steinhardt (eds). 2001. Sustaining the Global Farm. Selected papers from the 10th International Soil Conservation Organization Meeting held May 24-29, 1999 at Purdue University and the USDA-ARS National Soil Erosion Research Laboratory.

Characteristics and Socio-Economic Evaluation of Two Indigenous Soil and Water Conservation Systems

B. Kayombo, H.O. Dihenga and J.Ellis-Jones*

ABSTRACT

The most common indigenous soil and water conservation practices in Mbinga district are *ngoro* and *matuta* systems. The *ngoro* system enables the cultivation of land with steep slopes (10-60%) reducing soil erosion, maintaining fertility, and increasing soil moisture especially from April to July. *Matuta* with incorporation of plant residues have many of the advantages of increased fertility, organic matter content and associated soil improvements described for *ngoro*, but require more labor than *matuta* where crop residues are not incorporated.

The main factors that farmers would take into account in deciding whether to construct *ngoro* or *matuta* are productivity, labor availability, use of fertilizer, farming systems and tradition, in that order of importance.

Economic analysis has indicated that *ngoro* provides highest productivity where fertilizer is not applied, though at low soil fertility levels all systems are likely to give negative gross margins. Where fertilizer is applied the *matuta* systems are likely to give higher returns.

Long term productivity decline is considered a major problem for resource-poor farmers in the district. One of the main factors behind the decline in soil productivity is the decreasing fallow periods in combination with nil or low external inputs. New measures are required to support indigenous soil and water conservation systems. These are likely to include the use of infield measures that can improve soil moisture and nutrient availability. An important way forward is to identify farmer innovators at all resource levels, who experiment within the framework of their existing farming systems using locally available materials. Modern techniques need to encompass the flexibility of indigenous soil and water conservation systems, providing options that can be modified and adopted to fit local biophysical and socioeconomic circumstances.

INTRODUCTION

A number of large-scale land development projects with mechanized agricultural production were carried out in East Africa during the 1950-60s. However, the conclusions drawn from a critical appraisal of implemented large scale agricultural development schemes is far from encouraging. Failure of such schemes has been attributed to many factors, including socio-economic conditions and infrastructure (Baldwin, 1957), insufficient baseline data to enable adequate planning for resource development and management, failure of monsoons, "top down" approach taken by the majority of the projects and use of inappropriate technologies (Hudson, 1991; Reij, 1991). These barriers to agricultural development have received greater attention in recent years (Hudson, 1991; Baum et al., 1993) and have resulted in a paradigm shift. Previous top-down approaches which attempted to impose "improved" technology packages are being replaced by more facilitating/participative approaches to extension (FAO, 1995). In adopting such "bottom-up" approach, it is acknowledged that any new technology must accord with the experience of the user. Accordingly, IFAD (1992) states that the first step in the design of a new soil and water conservation programme should be the identification of indigenous farming systems and their conservation techniques. Central to this approach is utilizing traditional knowledge in the improvement of indigenous soil and water conservation techniques (Critchley, 1991).

The purpose of this paper is two-fold: (i) to describe the salient characteristics of two indigenous soil and water conservation systems, namely ***ngoro*** (or pits) and ***matuta*** (or ridges), and (ii) to examine the socio-economic (i.e. productivity) aspects of the systems, in Mbinga District of southwest Tanzania.

CHARACTERISTICS OF INDIGENOUS SOIL AND WATER CONSERVATION SYSTEMS

Location and agro-ecological environment

The main focus of the study are the Matengo Highlands and surrounding areas of the Mbinga district in South West Tanzania as shown in Fig. 1. Mbinga District is 11935 km^2 and can be divided into five agro-ecological zones (Fig. 1, Table 1).

The mountainous areas can be subdivided into High and Low Altitude zones; the High Altitude being considerably cooler with higher rainfall and has along with High Plateau the greatest potential for coffee production. The High Plateau is very similar in climatic condition and farming practices to the high altitude mountainous area but is characterized by its gentler slopes and shallower more erodible soils. The largest agro-ecological zone is the Rolling Hills where extensive deforestation, especially in the more heavily populated northern areas, is common.

*B.Kayombo, Botswana College of Agriculture, Private Bag 0027, Gaborone, Botswana; H.O.Dihenga, Sokoine University of Agriculture, P.O. Box 3000, Chuo Kikuu, Morogoro, Tanzania; J.Ellis-Jones, Silsoe Research Institute, Bedfordshire, MK45 4HS, United Kingdom. *Corresponding author: bkayombo@bca.bw

Table 1. Description of Agro-ecological zones

AGRO-ECOLOGICAL ZONE		ALTITUDE (metres ASL)	INDICATIVE RAINFALL (mm)	DESCRIPTION	% OF AREA CULTIVATED
Mountainous areas	High altitude	1600-1900	1400-1600	Strongly dissected mountains with steep slope and narrow valleys	80
	Low Altitude	1400-1600	1000-1400		
High Plateau (Hagati plateau)		1500	1400-1600	Gently rolling plateau at the top of the mountains	80
Rolling Hills	North	1300	1000-1200	Flat to undulating plains intermixed	66
	South	1200	1000-1200	with mountains up to peaks of 1600m	33
Lakeside		500-600	900-1400	Mainly flat with undulating hilly slopes rising to steep escarpment adjoining the highlands	20

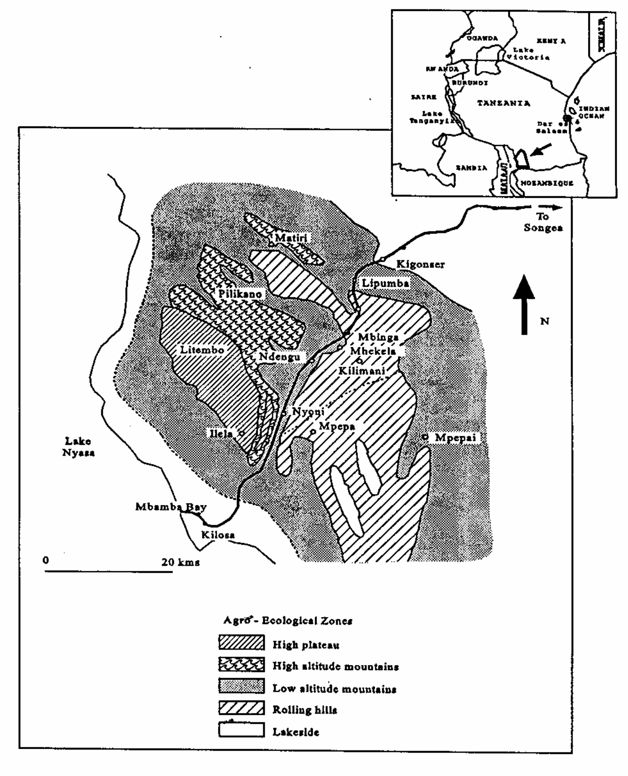
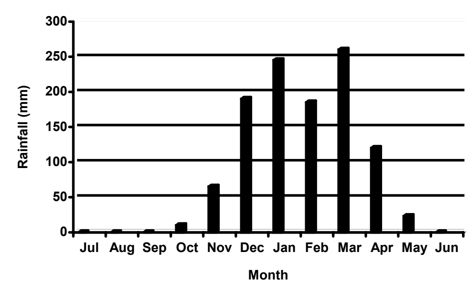


Figure 1. Agro-ecological zones of Mbinga District in Southwest Tanzania

Although population pressure in the South is less severe, migration from adjoining areas is resulting in rapid denudation of the *miombo* woodland. The Lakeside zone comprises a narrow coastal strip as well as the steep escarpment area immediately west of the Hagati plateau. It has a hot and humid climate very different from the rest of the Mbinga district and for this reason has been excluded from this study. The zones having the greatest percentage of their land under cultivation are clearly the Mountainous areas and High Plateau where the population densities are greatest.

The climate is temperate tropical with a unimodal rainfall pattern with a rainy season extending for six months with a cooler dry season for the remainder of the year. Average minimum and maximum temperatures are 19-23^{0}C and 29-31^0 C respectively. The average annual rainfall for

Fig 2. Ave monthly rainfall of Mbinga Town



the district is 1224 mm which varies from less than 1000mm to over 1600mm depending on altitude and direction. The average monthly rainfall distribution is shown in Fig.2.

The growing season extends from 6-7 months in the low altitude mountains and rolling hills areas and up to nine months in the high altitude areas and plateau. This allows only a single annual crop to be grown each year. Evapotranspiration data is not available but certainly between May and October evapotranspiration exceeds precipitation. Adequate soil moisture is therefore critical in achieving economic yields of beans, wheat and other dry season crops.The soils are Haplic or Humic acrisols (Oxisols, Ultisols) depending on their position in the toposequence. At higher elevations the most common soils used for crop production are deeply weathered highly leached yellow red, well drained with good permeability. Textures are largely sandy clay loams. On the plateau the soils tend to be shallower with impeded drainage in places. At lower elevations soils are less leached brown red sandy clay loams and sandy clays. In both elevations the major difference in soil type is the presence or absence of the top soil horizon due to soil erosion. Where the top soil is present, the organic matter content is high. Where the top soil has been lost, farmers cultivate the red subsoil.

The natural vegetation of the area is largely *miombo* woodland, dominated by *Julbernardia* and *Brachystegia spp*., which has almost totally disappeared in the Mountains and Plateau areas and is fast disappearing in other areas. At lower elevation secondary wooded grassland is common. Deforestation for the establishment of new lands is an ongoing process, especially in the lowland areas where *miombo* woodland still exists. In fact most of the wood consumed in Mbinga township comes from this area. In the Highlands and Rolling Hills North there is a shortage of wood and therefore increasing pressure on the remaining woodlands.

Socio-economic environment

The population is estimated to be 320 000 people with a growth rate of 3.4%. There are four main ethnic groups in the district; the Ngoni in the North-east, the Manda in the North, the Nyasa along the lakeside and the Matengo in the Highlands. The district is one of the wealthiest regions in Tanzania largely as a result of the introduction of coffee in the 1930s. As a result of the high agricultural potential, the district has the highest population density (32 people per km^2) in the south west region of Tanzania. The population is however unevenly distributed with highest concentrations in the mountainous areas with up to 120 persons/km^2. These parts are generally the ones with the longest tradition of growing coffee. The resulting high land pressure gives rise to intensive agricultural practices and rapid deforestation as well as considerable out migration especially of young men and families in an attempt to acquire land.

Almost all income in the area is derived from agriculture, coffee being the main cash source in the mountainous areas. Coffee can also be important for bartering when cash payments are delayed as in 1995. The area of coffee is still expanding as a result of high prices and assistance from an European Union (EU) funded project. At lower altitudes although coffee is still important, maize and beans tend to be more important as cash crops.

Transport infrastructure is in very poor condition and is a major constraint to increased production particularly in the mountainous areas. In most villages there are problems of accessibility during the rainy season with often no communications possible. This leads to problems supplying inputs and marketing produce.

The official marketing of agricultural commodities, mainly coffee but also maize and beans, has been through the Mbinga Cooperative Union (MBICU) with crop procurement undertaken through primary grass roots cooperatives. Many reforms have been introduced in the official marketing system especially with regards to the cooperative sector. Since 1990 the declared intention was to make the Cooperative Union the property of primary village cooperatives. However, since market deregulation in 1994 private operators have played an increasingly important role in both buying coffee and supplying fertilizers and chemicals. Input distribution largely takes place in the dry season and erratic input supplies is a major problem voiced by farmers.

Because of poor repayments of crop loans the Cooperative Rural Development Bank curtailed credit and is no longer functional in the district. The National Bank of Commerce operates in the district but provides little credit to coffee farmers. As a result most inputs are now paid for in cash, though a number of private coffee buyers are now introducing credit systems.

There is ongoing concern for the nutrition and health of children and women. Birth weights are low reflecting high work rates and poor nutrition of pregnant women. During the main cultivation period women work up to 12 hours per day constructing ***ngoro*** in addition to their household tasks. Lack of regular feeding of infants is said to be a cause of malnutrition related to the very high work burden on women.

Farming systems

Agriculture is entirely based on smallholder production with farm size varying from a minimum of one ha and to a maximum in excess of 12 ha.

The mean areas of farms and the major crops grown on each are shown in Table 2. Crops are either grown in mixed and pure cropping systems nearly always using ***ngoro*** or ***matuta*** except in wetland areas where they are planted on the flat, often with intricate drainage systems.

The season starts with the onset of the rains in November or December when maize and cassava are planted, with a second season planting in April or May for crops such as beans, wheat, potatoes and peas. The most common crop rotation on ***ngoro*** is beans with some planting of cassava followed by maize followed by a short 6-8 month fallow, which can be extended if productivity declines. On ***matuta*** rotations are usually continuous maize sometimes interplanted with beans in November, or beans planted on their own usually in December and sometimes in March or April. There is however considerable variation according to rainfall distribution, altitude, farmer preference and the incorporation of minor crops into the rotation as demonstrated in Table 4.

Some farmers keep the ***ngoro*** and ***matuta*** systems completely separate. Others will convert from ***matuta*** to ***ngoro*** when fertility declines. Sometimes April beans will be grown on ***matuta*** with a similar rotation to the ***ngoro*** system. Wheat may replace beans as an April planted crop especially in high altitude areas.

Table 2. Mean area of land (ha) per farmer under major food crops in the Different agro-ecological zones.

Crop	Mountains	Plateau	Rolling Hills North	Rolling Hills South
Coffee	0.9	0.9	0.65	0.45
Maize	1.0	0.9	1.5	1.7
Beans	0.36	0.5	0.8	0.6
Millet	-	0.02	0.06	0.4
Wheat	0.3	0.3	0.04	0.04
Cassava	0.01	1.3	0.5	0.04
TOTAL	**2.57**	**3.92**	**3.55**	**3.23**

Table 3. Cropping systems in Mbinga District.

Crop	Mountains: High altitude and Plateau	Mountains: Low altitude	Rolling Hills: North	Rolling Hills: South
Main food crops	Maize Cassava Wheat Potatoes	Maize Beans Cassava	Maize Beans Cassava	Maize Millet Beans
Main cash crops	Coffee	Coffee	Coffee Maize Beans	Maize Beans

Table 4. Typical crop rotations at lower altitudes

Conservation system	Year 1		Year 2		Year 3	
	April	December	April	December	April	December
Ngoro	Beans	Maize		Fallow	Beans	Maize
	Or wheat					
	Cassava				Cassava	
Matuta either		Maize	-	Maize	-	Maize
or		Maize	Beans		-	Beans
or		Maize/Beans		Maize/Beans	-	Maize/Beans

Animal populations in the district are low, making little contribution to the rural economy. There is little integration of livestock systems into crop production systems other than for manure. The cattle, goats, pigs and chickens are kept but in small numbers as shown in Table 5. The main uses for cattle are milk, meat and dowry.

The burning of woodland and grasses is common when opening up new land and the resulting ashes are used for planting of finger millet. Crop residues are rarely burnt in the ***ngoro*** field unless the land is intended for finger millet. When ***matuta*** are to be constructed burning is frequently carried out to reduce labor requirements. Most manure is used close to the homestead on coffee, fruit trees and rarely maize. Due to the low numbers of livestock in the area manure is always in short supply. Most farmers apply nitrogenous fertilizers to their coffee crops, occasionally to maize but almost never to other crops.

Soil and water conservation systems

In annual cropping systems primary land preparation is undertaken by hand using either the ***ngoro*** system or one of two types of ***matuta***: those which have plant residue incorporated into them or those which do not. Flat cultivation occurs only in the valley bottoms. In perennial cropping systems (primarily coffee), mulching is commonly carried out with material carried from nearby fields or from the leaves of *Grevellia robusta*, which is common as a shade tree for coffee.

Ngoro system

The most conspicuous and original feature of agriculture in the area is the ***ngoro*** system, enabling the cultivation of land with steep slopes to reducing erosion, maintaining fertility and increasing soil moisture especially from April to July. ***Ngoro*** are used almost exclusively for food crops within a slope range of 10% to 60%. However they are dependent on a fallow period the minimum of which is 6-8 months. The length of fallow in the rotation varies according to population and hence cropping intensity. As population density increases fallow decreases in terms of both duration and percentage of total land use. Table 6 indicates the periods of cultivation and fallow in each zone. The ***ngoro*** are formed in March/April and are constructed as follows: Grass is slashed with a *nyengo* (sickle) and lain in a matrix of discrete squares or rectangles with side dimensions ranging from 2.0-2.5 m. After drying for a week, soil is dug by *jembe* (hoe) from the centre of these squares and thrown over the grass to form bunds on all sides and consequently a pit (***ngoro***) in the centre. The bund walls thus consist of a layer of grass sandwiched between a layer of top soil and the original soil surface beneath it. Throughout the year weeds and crop debris are thrown into the pits to form compost. Unless an extended fallow period is used, pits are reformed every 2 years after 6-8 month short fallow. Burning on ***ngoro*** was rare but is now increasing to reduce crop residues and labor requirements. The greatest concentration of ***ngoro*** is with the Matengo people in the mountainous zone of Mbinga. However, ***ngoro*** has spread to the lowlands as a result of mixed marriages and migration of Matengo people. Estimates provided by the District Agriculture and Livestock Development Office (DALDO) staff on the relative use of ***ngoro*** and ***matuta*** on food crops are shown on Table 7.

Although the ***ngoro*** system sustains soil fertility at a higher level compared to the ***matuta*** system, there is a general belief that, due to decreased fallow periods, the system is no longer sustainable without the addition of fertilizer. This constitutes a serious problem as presently fertilizer is principally applied to the cash crops only.

Matuta system

There are basically two types of ***matuta***, those with organic matter incorporated and those where organic matter is burnt off first.

Table 5. Livestock ownership in Mbinga District.

Livestock	No. in district 1991	Average per household
Goats	103 424	2
Cows	46 085	0-1
Sheep	15 824	Negligible
Pigs	46 465	2-3
Chickens	228 245	5-10
Ducks	10 529	1-2

Table 6. Average duration of cultivation (years) and fallow in the highlands Source: Derived from ICRA (1991)

Agro ecological zone	Continuous cultivation	Fallow period
Mountains	6.4	1.2
Plateau	6.6	1.1
Rolling Hills North	3.5	1.9
Rolling Hills South	4.0	1.7

Table 7. The extent (%) of *ngoro* and ridges.

Land preparation system	Highlands (Mountains and Plateau)	Rolling Hills	
		North	South
Ngoro	95	70	30
Matuta	5	30	70

Matuta with incorporation of plant residues are formed by slashing grass and crop residues, laying them in parallel lines across the slope and covering with soil to form ridges. When the ridges are reformed in the following year, grass is cut and lain in the furrows before being covered with soil dug from the old ridges. This method eliminates the need for burning and has many of the advantages of increased fertility, organic matter content, and associated soil improvements described for ***ngoro***, but requires more labor than ***matuta*** where plant residues are not incorporated. ***Matuta*** with no incorporation of crop residues are formed in a similar way to the ones described above, but in this case the crop residue is burnt and the soil earthed up using hand hoes. ***Matuta*** are the most common method of land use preparation on gently sloping land where they too offer a similar degree of erosion control as ***ngoro***. When there is no incorporation of organic matter, fertility can decrease rapidly and longer fallow periods are required. Moisture conservation is poorer in ***matuta*** than in ***ngoro*** due to more rainfall being lost as runoff and a lower water holding capacity of the soil, attributed to the lower levels of organic matter.

Division of labor

There is a fairly clear division of labor between men and women. The husband is the decision maker controlling the allocation of resources. Most of the work on food crops is undertaken by women, as are most household tasks. Making of ***matuta*** is jointly undertaken but the construction of ***ngoro*** is traditionally female work, except for initial land clearing and laying out the grass matrix. Men are mainly involved with coffee production and view the ***ngoro*** as being too laborious, even if payment is offered. Money from sale of coffee is always kept by men. Women retain income from sale of maize and beans unless there is no coffee when men also retain this.

Table 8 summarizes the division of labor.

METHODOLOGY FOR SOCIO-ECONOMIC EVALUATION

An initial Participatory Rural Appraisal (PRA) was conducted in late 1994. The techniques used were based on participatory approaches, where a multi-disciplinary team consulted and discussed with local leaders, groups, individual farmers, as well as support institutions promoting agricultural development in the district. The PRA was carried out in two phases. Phase 1 involved visits to four villages, Ilela on the High Plateau, Mpepai in the Rolling Hills South, Kindimba in the Mountainous areas and Kilosa in the lakeside area. This provided an opportunity to build up a general picture of the organization of local government and agriculture in the villages as well as major problems being experienced. In each village the PRA team held group interviews with up to 25 farmers and staff of local schools and institutions. Copies of any existing information such as rainfall records and reports held in the district were also obtained. Phase 2 was carried out some two weeks later and involved in depth discussion with DALDO staff, other development institutions and individual farmers with greater emphasis on soil and water conservation technologies. The team undertook detailed traverses across farmers fields examining soil types, land use and soil& water management techniques as well as exploratory characterization of ***ngoro*** and ***matuta*** dimensions. The advantages and disadvantages of each land preparation method were discussed at length with farmers together with more general information on local farming systems.

After the PRA, farmers were identified from two villages, namely Lipumba and Mhekela, to participate in farming systems monitoring. Nine households from each of the two villages were selected as being representatives of farmers from different agro-ecological and socio-economic backgrounds. Individual households from the two villages provided details of their farms and crop management practices over a 12-month period. Over a two-year period interviews were held with each household and workshops conducted in each village for farmers, community leaders and extension agents during and at the end of each season to establish within a group forum farmers' views and their evaluation criteria on the comparative advantages of ***ngoro*** and ***matuta***.

A detailed economic analysis was undertaken to establish productivity indicators of ***ngoro*** and ***matuta*** systems. Estimates of labor requirements were derived through small group and plenary discussion at farmers' workshops held during 1996 and 1997 at Lipumba and Mhekela. These rates were similar to labor rates recorded on experimental plots and field observations made while farmers were working in their own fields. Farmers' estimates were therefore, used where labor rates were required in the analysis. Gross margins were calculated based on crops grown with-and-without additional fertilizer application. No-fertilizer application is the norm rather than the exception by many of the resource poor households in the district. However, rising incomes due to increased productivity of coffee, declining soil fertility and increased availability of fertilizer has encouraged farmers with greater access to cash to increasingly use fertilizer on both coffee and their annual crops.

SOCIO-ECONOMIC EVALUATION

Farmers' perceptions and evaluation criteria

The main conclusions emerging from farmers' views and their evaluation criteria on the comparative advantages of ***ngoro*** and ***matuta*** are shown in Table 9.

Farmers' views confirmed that the most important benefits relate to their ability to increase productivity and are erosion control, fertility maintenance and moisture retention. Also important are the fact that higher yields are achieved with ***ngoro*** in comparison to ***matuta*** when no fertilizer is applied, April planted bean yields are higher and land preparation is only undertaken once every two years. Of importance was the view that ***matuta*** can be as effective as ***ngoro*** when properly constructed and organic matter is incorporated. They require less labor and give higher yields when fertilizer is used. Other important benefits were that

Table 8. Division of labor.

Activity	Men	Women
Decision making	*	
Slashing grass/clearing land	*	
Grass matrix making	*	
Digging and seeding ***ngoro***		*
Building ***matuta***	*	*
Pest control/ harvesting	*	*
Food crop cultivation		*
Marketing	*	
Collecting firewood		*
Collecting water		*
Household/domestic tasks		*

Table 9. Farmers' ranking of *ngoro* and *matuta*.

Ngoro	Ranking	Matuta	Ranking
Erosion control	1	Can be as effective as ***ngoro*** in controlling soil erosion when organic matter is incorporated	1
Provides better moisture in soil	2	Requires less labor than ***ngoro***	2
Retains fertility better when no fertilizer is applied	3	Gives higher yields than ***ngoro*** when fertilizer is applied	3
Gives higher yields than ***matuta*** when no fertilizer is applied	4	Men and women share the work	4
Best on steep slopes	5	Best for intercropping maize and beans	5
Best for beans planted in March/April	6	Easier to plant than ***ngoro***	6
Made every two years	7	Best for December planted beans	7
Cassava can be grown on ***ngoro***	8	Easier to fertilize than ***ngoro*** and uses less fertilizer	8
Traditional system	9	Easier to employ people to construct	9
Helps people not to migrate	10	Easier to mechanize	10

Table 10. Farmers' criteria used in deciding whether to construct *ngoro* or *Matuta*.

Criteria	Ranking
Soil erosion problems	1
Labor availability (family or hired, gender divisions)	2
Cash to buy fertilizer	3
Crop rotations	4
Tradition	5

Table 11. Labor requirements for *ngoro* and *matuta* (days per ha).

	Ngoro		***Matuta***					
			With organic matter			**Without organic matter**		
Planting date	**Maize Dec**	**Beans Apr**	**Maize Dec**	**Beans Apr**	**Beans Dec**	**Maize Dec**	**Beans Apr**	**Beans Dec**
Activity								
Burning	0	0	0	0	0	3	3	3
Slashing	5	10	5	10	10	0	0	0
Arranging grass	0	13	0	13	8	0	0	0
Pitting/ridging	13	30	10	10	13	8	8	8
Planting	8	5	8	5	5	8	5	5
Fertilising	5	0	5	0	0	5	0	0
Weeding	13	0	13	0	13	13	0	13
Pest control	5	5	5	5	5	5	5	5
Harvest	8	3	8	3	5	8	3	5
Total	**55**	**65**	**53**	**45**	**58**	**48**	**23**	**38**
System Requirement	**120**		**98**			**71**		

men and women shared the work and the ***matuta*** were better for intercropping. However, decreasing labor availability was a major concern to farmers, reasons advanced being: illness and disease; searching for food; deaths and funerals; drinking; loitering of youths; ceremonial functions; and increased court cases.

The criteria used in deciding whether to construct ***ngoro*** or ***matuta*** are shown in Table 10. Control of soil erosion, labor availability, and having the finance available to buy fertilizer ranked highest in deciding the conservation measure to use.

Labor requirements

The labor requirements for ***ngoro*** and ***matuta*** are given in Table 11. It can be clearly seen that ***ngoro*** require, not only additional labor for individual crops, but when the system is compared over a two year period, ***ngoro*** require between 20% and 70% more labor than ***matuta***, with and without incorporated organic residues. Much of the additional labor required for ***ngoro***, especially pitting, is provided by women.

Economic analysis of *ngoro* and *matuta* systems

The following economic analysis (Tables 12,13) is based on the *ngoro* cropping calendar when beans and maize are grown over a two year period in Mbinga district.

Table 12 shows the low yields achieved on both ***ngoro*** and ***matuta*** without fertilizer, giving negative gross margins in all cases. However, when the cost of labor is excluded positive returns are achieved, although the financial returns per labor day are still considerably less than the cost of hiring labor (US$1.50 per day).

All productivity indicators (yields, gross margins and returns to cash and labor) indicate that ***ngoro*** is the most productive system for both maize and beans when fertilizer is not used. The productivity of the ***matuta*** system is less straightforward, as the incorporation of organic matter residues have a strong impact on the productivity of the maize crop, but little or no impact on the productivity of the bean crop. However, in contrast to the maize crop, beans grown on ***matuta*** after organic matter residues had been

Table 12. Economic analysis of maize and bean production on *ngoro* and *matuta*

Crop	Conservation system	Yield[1] Kg/ha	Inputs		Gross margins ($) per ha[4]		Returns to		Rank
			Labor[2] Days/ha	Materials[3]$	Includ. labor	Exc. labor	Cash[5] %	Labor[6] $ per day	
Maize	***Ngoro***	657	55	14	-27	57	423	1.04	1
	Matuta+OM	562	53	13	-33	48	373	0.91	2
	Matuta-OM	403	48	10	-65	8	79	0.16	3
Beans	***Ngoro***	273	65	120	-10	90	75	1.38	1
	Matuta+OM	155	45	119	-69	0	0	-0.01	3
	Matuta-OM	161	23	119	-154	4	4	0.20	2

Notes: 1 Yields are based on an average of trial results for 1996 and 1997
2 Labor rates are based on those shown in table x and have been valued at Tsh 1000 (US$1.50) per day.
3 Materials include local seed varieties and bags at 1997 market prices
4 Gross-margins have been calculated with and without the cost of labor, in order to show the effect of household supplied labor
5 The value of gross income (yield market prices) as a percentage of cash outlay (excluding household supplied labor)
6 Gross-margin excluding labor costs divided by labor input

Table 13. Economic analysis of maize production on different sized *ngoro* and *matuta* with-and-without fertilizer

	Conservation system	Yield Kg/ha	Inputs		Gross margin per ha		Returns to		Rank
			Labor[2] Days/ha	Materials $	Inc. Labor	Exc. Labor	Cash %	Labor $ per day	
With[1] Fertilizer	Large ***ngoro***	3111	57	160	90	167	105	2.93	4
	Medium ***ngoro***	3745	62	164	151	229	139	3.69	3
	Small ***ngoro***	3851	64	165	162	239	145	3.74	2
	Staggered ***ngoro***	2563	64	156	47	114	73	1.77	5
	Matuta+OM	5162	55	175	287	367	210	6.73	1
Without Fertilizer	Large ***ngoro***	1141	55	17	21	103	613	1.87	3
	Medium ***ngoro***	1559	60	20	61	144	721	2.40	1
	Small ***ngoro***	937	62	15	83	83	544	1.34	4
	Staggered ***ngoro***	669	62	13	-25	57	430	0.92	5
	Matuta+OM	1270	53	18	36	116	650	2.20	2

Notes 1 Fertilizer includes 150 kg triple superphosphate and 50 kg of urea.
2 Based on rates shown in Table 11 adjusted by the additional labor for different ***ngoro*** size and fertilizer application requirements.

burnt, gave a higher return to labor. When labor is in short supply, it is therefore a rational (short term) decision to burn the organic matter. Longer-term analysis however, shows that this is not the case and incorporation of organic matter is preferable (Ellis-Jones and Tengberg, 2000).

Where fertilizer was applied to differently sized ***ngoro*** and ***matuta***, the improved fertility increased productivity in all situations (Table 13). ***Matuta*** give the highest returns in terms of yield, gross margin and returns to labor and cash. It is interesting to note that the small and medium ***ngoro*** give higher returns than large ***ngoro*** despite their slightly higher labor requirements.

Without fertilizer the medium sized ***ngoro*** give higher returns than ***matuta***. Small and staggered ***ngoro*** give substantial lower returns than ***matuta.***

CONCLUSIONS

The most common indigenous soil and water conservation practices in Mbinga district are ***ngoro*** and ***matuta*** systems. The ***ngoro*** system enables the cultivation of land with steep slopes (10-60%) reducing soil erosion, maintaining fertility and increasing soil moisture especially from April to July. ***Matuta*** with incorporation of plant residues have many of the advantages of increased fertility, organic matter content and associated soil improvements described for ***ngoro***, but require more labor than ***matuta*** where plant residues are not incorporated. The main factors that farmers would take into account in deciding whether to construct ***ngoro*** or ***matuta*** are productivity, labor availability, use of fertilizer, farming system and tradition, in that order of importance.

Economic analysis has indicated that ***ngoro*** provides highest productivity where fertilizer is not applied; though at low soil fertility levels, all systems are likely to give negative gross margins. Where fertilizer is applied the ***matuta*** system is likely to give higher returns.

Although the ***ngoro*** system has maintained the productivity of local farming systems, on its own, it cannot sustain the intensification that is now occurring. Increasing labor costs and decreasing availability of organic materials make it necessary to adapt ***ngoro***. ***Matuta*** with organic matter incorporation is already one such option. Increased use of fertilizer is occurring partly as a response to increased labor costs and partly due to declining soil fertility.

Long-term productivity decline is considered a major problem for resource-poor farmers as has been illustrated in this study. One of the main factors behind the decline in soil productivity is the decreasing fallow periods in combination with nil or low external inputs.

New measures are required to support indigenous soil and water conservation systems. These are likely to include the use of infield measures that can improve soil moisture and nutrient availability and include encouragement of continued incorporation of organic matter from crop residues and green manures and use of soil improving hedges around field boundaries to provide organic materials for incorporation into soil. Research and capacity building needs to be oriented towards development and extension of technologies adapted to land-user conditions, which create incentives in the short run. An important way forward is to identify farmer innovators at all resource levels, who experiment within the framework of their existing farming systems using locally available materials. Such an approach to soil productivity enhancement is likely to build on the strength and, at the same time, recognise the threats from their inherent weaknesses. Modern techniques need to encompass the flexibility of indigenous soil and water conservation systems, providing options that can be modified and adopted to fit local biophysical and socio-economic circumstances.

ACKNOWLEDGEMENTS

The work described in this paper formed part of the Collaborative Environment Research Project funded by the Department for International Development (DFID) and managed by Silsoe Research Institute (SRI).

REFERENCES

Baldwin, K.D.S., 1957. The Nigeria agricultural project: An experiment in Africa development. Blackwell, Oxford.

Baum, E., P. Wolff and M. Zobisch. (Eds), 1993. Acceptance of Soil and Water Conservation Strategies and Technologies. DITSL, Germany.

Critchley, W.R.S., 1991. Looking after our land: New approaches to soil and water conservation in dryland Africa. Oxford publications, Oxford.

Ellis-Jones, J. and A. Tengberg. 2000. The impact of indigenous soil and water conservation practices on soil productivity: Examples from Kenya, Tanzania and Uganda. Land Degrad. Develop., 11:19-36.

Ellis-Jones, J., L. Martin, B. Kayombo, H.O. Dihenga, S. Thadei and T.J. Willcocks. 1994. A participatory rural appraisal of Mbinga District, Tanzania with emphasis on existing soil and water conservation systems. Project Working Document OD/94/25.

FAO, 1995. Agricultural investment to promote improved capture and use of rainfall in dry land farming. FAO Investment Centre Technical Paper 10, FAO, Rome.

Hudson, N.W. 1991. A study of the reasons for success or failure of soil conservation projects. FAO Soils Bulletin 64. FAO, Rome.

ICRA, 1991. Analysis of the coffee based farming system in the Matengo Highlands, Mbinga District, Tanzania. ICRA Wageningen, The Netherlands, Working Document Series 15.

IFAD, 1992. Soil and water conservation in Sub-Saharan Africa. International Fund For Agricultural Development, Rome.

Reij, C. 1991. Indigenous soil and water conservation in Africa. IIED Gatekeeper Series No. 27, IIED, London.