Indigenous conservation tillage system in East Africa with an example of their evaluation from South West Tanzania

by

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Abstract

Available literature in East Africa reveals that indigenous conservation techniques (ICT) are prevalent in areas of water-deficit conditions and in semi-arid zones. Due to changing natural and socio-economic environment, some of these ICT systems are beginning to show signs of decline. To reverse the declining trend, there is paramount need to understand these systems as a first step towards their improvement. The socio-economic evaluation of ICT techniques in Mbinga District of S.W. Tanzania has shown that Ngoro cultivation is efficient at controlling soil erosion, increasing soil moisture at critical times of the year and maintaining soil fertility. The problems associated with it, notably decreasing fallow periods and high labour requirement, indicate their declining use. The technical evaluation has shown that compared to ridges, when Ngoros are intact, they increase soil moisture and consequently yields. When badly degraded, soil moisture is decreased but despite this, maize growth and yields are better than on ridges, when no fertiliser is used. In Ngoro, the majority of eroded soil is re-deposited into the pit, whereas on ridges it is often transported elsewhere. The immediate future challenge is to build productivity enhancing improvements into the present system without destroying its unique advantages.

1. Introduction

A number of large-scale land development projects with mechanised 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 (De Wild, 1967),
- 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 approach which attempted to impose 'improved' technology packages are being replaced by more facilitating and participative approaches to extension (FAO, 1995). In adopting such 'bottom-up' approaches, 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 utilising traditional knowledge in the improvement of indigenous soil and water conservation techniques (Critchley, 1992). Indigenous Conservation Tillage (ICT) systems in this context mean all those traditional cultivation practices which conserve soil and water and increase soil fertility for increased crop production. In East Africa, the manual effort provides all the mechanical power in agricultural operations including seedbed preparation and weed control (i.e. hand hoeing, slash and burn).

1.1 Objectives

The purpose of this paper is two-fold:

(i) to document existing indigenous conservation tillage (ICT) systems and

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(ii) to analyse the usefulness and shortcomings of ICT using a case study from South West Tanzania.

2. Conservation tillage systems

2.1 Natural and socio-economic environment

The seasonal rainfall patterns are governed by the seasonal shifts and intensity of the low pressure Inter Tropical Convergence Zone (ITCZ). Semi arid areas receive average annual rainfall of 800-1000mm. Potential evaporation ranges from 1450 to 2200mm. The rainfall though low and erratic, occurs in high intensities of short duration and is highly erosive. High amounts of runoff are often generated from these storms owing to inherent low infiltration rates of the soils. Concentrated runoff flows are responsible for the severe erosion that occurs in these marginal rainfall areas.

The most dominant soils in marginal rainfall area of East Africa are Luvisols, Acrisols and Vertisols. Except for the vertisols, the other two soils are characterised by shallow soils with inherent low organic matter, water retention capacity, salt and sodium content and strong surface sealing and crusting properties. The dominant clays of Luvisols and Acrisols are usually of the 1:1 ratio (kaolinite). Water infiltration in the soils is rather low especially in the B-horizons where the textures are heavy. Luvisols and Acrisols are often cropped during the rainy season. Vertisols are characterised as deep soils having moderate to high salt and sodium content, montmorillonitic (2:1) clay mineralogy, and low infiltration rates. Vertisols are usually cropped after the rainy season.

The major crops grown in semi arid areas of East Africa include maize, beans, sorghum, millet, cassava, pigeon peas, sweet potatoes, cowpeas, groundnuts and cotton. Crop performance and yields are significantly influenced by the amount of rainfall and distribution. As a result of inherent soil moisture deficits, the period of cropping is limited to the rainy season. Intercropping is a very common farming practice as it minimises the risks of crop failure owing to unexpected soil moisture deficits.

During the past two to three decades, human and livestock population in semi arid areas of East Africa has significantly increased and consequently led to an over exploitation of the limited land and water resources. Soil and vegetative degradation have become widespread owing to overgrazing, deforestation, burning and over-cultivation. Accompanying this unprecedented population increase, is the fragmentation of landholdings and sedentarization of pastoralists which has destabilised the very fragile ecology of the areas (Biamah et al., 1993). This has adversely affected food and fodder production and left the entire population vulnerable to food and fibre shortages. Unpredictable weather conditions have exacerbated the problems and further eroded the production potential of the resource base.

2.2 Indigenous conservation tillage systems

ICT systems are prevalent in areas with water-deficit conditions and in semi-arid zones where the hand-hoe is the main tillage tool backed-up by measures which improve soil-water-fertility conservation for crop production.

2.2.1 Kenya

The ICT techniques described below are the most common among smallholder farmers in Mbeere District of Eastern Province in Kenya.

Trash lines are formed by placing crop residues in lines, across the field. They are intended to impede runoff and enhance infiltration, but as Critchley (1992) states, their effectiveness is dependent on the composition and care with which they are established. According to Altshul and Okoba (1996), the technique was present before (1907) and has been passed down orally from generation to generation. The trash lines are constructed mainly from sorghum and millet stovers which are slower to decompose and are of lower palatability to livestock than maize stovers. The position of most trash lines is not fixed but instead new trash is placed 3 to 5m up slope each season.

Trash lines are not a permanent ICT measure and they are destroyed by ants and termites. They can withstand deluges of water because, being permeable, they ‘leak’ water. Furthermore, the decomposition of trash line material improves soil fertility.

Stone-bunds are a popular technique in stony areas and are a practical method of clearing stones from cultivated land. Their permanent nature makes them more popular with farmers than trash lines but they are also more labour intensive. The bunds are semi-permeable; allowing water to pass through but retaining soil and the process of cultivation on the inter-bund areas leads to the formation of natural benches over time. Stone bunds are found on slopes of upto 45 percent. On older farms, the bunds can be very large wall-like structures, built with large stones on the outside and the wall centre filled in with smaller stones. These large bunds may take several years to be completed, with a new course of stones being laid each season as time allows. Like trash lines, stone bunds have been

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traditionally used for several generations (Atshul and Okoba, 1996).

Log lines are only found on recently cleared land. The trunks left standing after the slash and burn cycle are felled and used to make the lines, which may be filled out using crop residues or weeds. Competition for log use exists between log lines and charcoal production and for this reason the lines are mostly constructed from softwood, which has low economic value. Some farmers compromise by constructing log lines from hardwoods and then burning the logs for charcoal after the terrace has formed. Like trash lines, log lines are destroyed by ants and termites. The technique is dying out as an ICT measure due to increasing population density, which has led to a decline in shifting cultivation (Atshul and Okoba, 1996).

Retention ditches are used in steep areas of Kenya, where runoff is captured and allowed to infiltrate for crop roots to tap (Thomas and Biamah, 1991).

2.2.2 Tanzania

Stone and earth terraces have been used by smallholder farmers for several generations in a number of areas in Tanzania. Stones were collected and built into terraces by inhabitants on densely populated Ukara Island in Lake Victoria to protect and increase cultivated land whose fertility has continuously been revamped by composting plant residues and addition of animal manure (Allan, 1965). The 'ladder terraces' of the Uluguru Mountains (in Morogoro) are shaped terraces which take the form of steps across the hillsides constructed when strips of plant waste are covered with soil dragged from above. The resultant high content of incorporated organic matter increases soil fertility as well as promoting rainfall infiltration (Temple, 1972).

Ridges (with-and-without incorporation of organic residues) are widely used in the Southern Highlands (of Iringa, Ruvuma and Rukwa) on slopes of 4-20% to grow maize, wheat, groundnuts, round and sweet potatoes. These ridges control soil erosion and retain some moisture as they are usually constructed on the contour (BACAS, 1993).

Tied ridges which are parallel ridges with earthen bunds constructed at right angles to them, at intervals of 1-4m), are used in growing maize and other grain crops in Mwanza and Shinyanga in the LakeVictoria zone although their popularity has considerably declined in recent years due to the amount of labour required under hand-hoe cultivation. The tied ridges, nevertheless, create a series of individual basins that increase the surface retention capacity, decreasing runoff, and increasing crop growth and yields (Prentice, 1946; Kayombo, 1993).

Ngoro or Matengo pit system of soil fertility and crop yield enhancement, found on steep slopes of Mbinga District of Southwest Tanzania, has been in use for at least 200 years and currently extend over some 18,000 ha (Allan, 1965; Kayombo and Dihenga, 1993). It consists of a series of regular pits, 1.5m square and 10-50cm deep, which from a distance resemble a honeycomb. The ridges are built on top of lines of cut grass which decomposes to release nutrients to the soil. Crops are only grown on the ridges, not in the pit itself.

Soil and water conservation as a result of water being trapped in the pits, reduces erosivity. The increased soil organic content encourages granulation hence aggregate stability. The *Ngoro* are also likely to create a sheltered microclimate. A combination of these factors allows beans, planted towards the end of the rains, in March/April, to be cropped on residual soil moisture.

Floodwater harvesting (FWH) is practised by smallholder farmers of Ukara Island in Lake Victoria to raise crops. The runoff provides water and fertile sediment for crop growth in gullies. Farmers use stone barriers to create small-scale silt traps. Alluvium is trapped and fertile gardens are created for the production of fruits and vegetables (Allan, 1965).

FWH is also being used to support paddy production on "mbuga" soils which are vertic, black-grey cracking clays around Dodoma, Singida, Tabora, Shinyanga and Mwanza. Farmers in these regions have developed an elaborate system of retaining the seasonal flood in bunded basins called *majaruba*. Records show that the development of this system started in the early 1940's (Allnutt, 1942). It is estimated that 32% of rice in Tanzania is produced under the *majaruba* system [Kanyeka et al., 1994). In Shinyanga and Tabora Regions for example, valley fields are subdivided by bunds of 25-100 cm height to form cultivated reservoirs or *majaruba* which are transplanted with rice crop (Mwakalila and Hatibu, 1992). The importance of this runoff farming is illustrated by the biggest increase in rice production in Tanzania over a 15 year period occurring in the semi-arid marginal areas (MoA, 1993). Yields are, however, still low compared to those of well-managed irrigation projects (6t/ha) (Hatibu et al., 1997).

Vinyungu, an ingenuous camber-bed type of cultivation, is practised by smallholder farmers in Makete, Ludewa, Mufindi and Njombe districts of Iringa administrative region to grow maize, beans,

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peas and vegetables during the dry (June-November) season. This practice is commonly used on heavy soils (clays) found in wet valley bottoms and other low-lying areas. The ridges are built up higher (up to 0.6m) and wider (up to 5-20m), with a cambered surface sloping down to the open drain on either side. They form a significant source of green produce for the urban centres of these districts in the dry season.

2.2.3 Uganda

Knowledge on existing ICT techniques comes from Kamwezi subcounty, Kabale District, in the highland area of South West Uganda. This area is renowned for its history of high population densities, land degradation and soil conservation programmes (Tukahirwa, 1995). Kamwezi lies at altitudes of 1400-2000m with a mean annual rainfall of 830mm. Farmers are, however, able to successfully grow bananas with about half the annual rainfall received by most banana growers in the world (Gowen, 1995). This has been possible due primarily to the persistent use of ICT techniques by local farmers under the water deficit conditions of Kamwezi. Among the well-known ICT techniques are the trashlines and banana mulching.

Trashlines are used on slopes of 20 to 30%, in a range of annual crops including maize, sorghum, beans, peas, cassava, round and sweet potatoes. The indigenous practice is to leave the land fallow after harvest, during the non-cropping season, allowing weed cover to develop thus protecting the soil surface from erosion. Land preparation includes seedbed preparation and heaping of trash and previous crop residues in lines along the contour. Some farmers favour annual movement of trashlines so that fertility around them is spread across the field. The major improvements to crop yields and the soil in the vicinity of the trashline, however, occur after the trashline has been in a single position for two seasons (Briggs et al., 1996).

Banana mulching on the plantation floor is used to conserve soil and water, to maintain soil fertility and to reduce weed growth. Harvested rainwater is also led into banana plantations via interception ditches. Banana mulching is a century old tradition. The indigenous banana mulching practice uses a mix of four different mulch components, namely, bean and sorghum stover, banana pseudo stem, and grass.

The two above and other ICT techniques, including their purposes and where they are used, are shown in Table 1.

Existing ICT techniques in East Africa are summarised in Table 2. The following factors (acting singly or in combination), as reported by Critchley et al., (1994), have allowed these ICT techniques to thrive to the present time:

1. A historical obligation to produce crops on hillsides and mountain slopes where the need to preserve the thin topsoil layer as a growing medium is paramount;
2. Population pressure and
3. Influence of land tenure.

These conditions favouring the persistence of ICT techniques provide us with guidelines on how to improve them as need arises. The first step in this direction is to analyse the usefulness and shortcomings of ICT techniques. Socio-economic and technical evaluation of ICT techniques are currently being carried out in Kenya (Altshul et al., 1996; Okoba et al., 1996) and Uganda (Briggs et al., 1996). A socio-economic and technical evaluation of ICT techniques in Mbinga District of South West Tanzania is given below.

2.3 Socio-economic and technical evaluation of ICT techniques in Mbinga District of South West Tanzania

The socio-economic and technical evaluation of ICT techniques in Mbinga District aimed at:

i) examining the socio-economic (productivity) aspects of the *Ngoro* compared to the use of ridges
ii) examining the technical (physical) aspects of the *Ngoro* compared to ridge cultivation on 15, 40 and 45% slopes.

2.3.1 Socio-economic evaluation

This involved a Participatory Rural Appraisal (PRA) in late 1994 followed by monitoring of nine farmers from two villages over a 12 month period selected as being representative of farmers with different socio-economic backgrounds and access to resources. Interviews were also held with each farmer on two separate occasions. A workshop was conducted in each village with the farmers and other community leaders in January 1996.

2.3.2 Locations and agro-ecological environment

The main focus for the project are the Matengo Highlands and surrounding areas of the Mbinga district in South West Tanzania. Mbinga District is 11935km^2 and can be divided into five agro-ecological zones: high and low altitude mountains,

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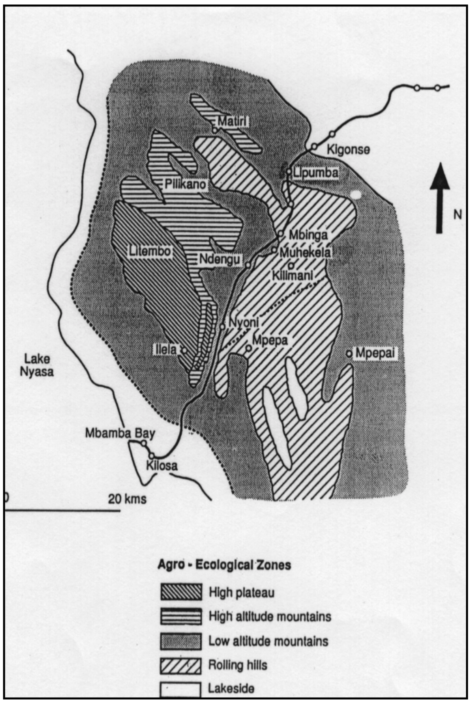
a high plateau, rolling hills and a lakeside zone. These are shown in Table 3 as well as Map 1.



Map 1: Agro-ecological zones of the Matengo Highlands area of Mbinga district

The climate can be described as temperate tropical with a unimodal rainfall pattern. The rain season extends for at least six months with a colder dry season for the remainder of the year. Average minimum and maximum temperatures are 19-23°C and 29-31°C respectively. The average annual rainfall for the district is 1224 mm. Unfortunately no long-term rainfall records exist except for Mbinga town which averages 1064 mm per annum. Monthly distribution is shown in Figure 1. The onset of the rains at the end of November is fairly reliable. The growing season extends from 6-7 months in the low altitude mountains to 9 months in the high altitude areas and plateau. Evapotranspiration data is not available but between May and October evapotranspiration exceeds precipitation. Adequate soil moisture is, therefore, critical in achieving economic yields in beans, wheat and other dry season crops.

The soils are Haplic or Humic acrisols depending on their position in the toposequence (ICRA, 1991). At higher elevations the most common soils used for crop production are deeply weathered highly leached yellow red soils which are well drained with good permeability. Textures are largely sandy clay loams. On the plateau, soils tend to be shallower with impeded drainage in places. At lower elevations soils are less leached brown red in colour sandy clay loams and sandy clays. Shortages of nitrogen, phosphorus and micro nutrients particularly zinc and copper are common. The relatively low incidence of soil erosion can be largely attributed to high inflation rates combined with the *ngoro* land preparation practice.

The natural vegetation of the area is largely Miombo woodland, dominated by Julbernardia and Brachystegia, which has almost totally disappeared in the Mountains and Plateau 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, with most of the wood consumed in Mbinga coming from this area. In the Highlands and Rolling Hills North, there is a shortage of wood and therefore increasing pressure on the remaining woodlands.

2.3.3 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 Matengo in the Highlands, Ngoni in the North-east, the Manda in the East, the Nyasa along the lakeside. 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). The resulting high land pressure gives rise to intensive agricultural practices and recent deforestation as well as considerable out migration especially of young men and families in an attempt to acquire land in other areas. Almost all income in the area is derived from agriculture, coffee being the main cash source. At lower altitudes although coffee is still important maize and beans are 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 these are problems of accessibility during the rainy season. This leads to problems of supplying inputs and marketing produce. The official marketing of agricultural commodities, mostly coffee but also maize and beans, has been through the Mbinga Cooperative Union (MBICU) with crop procurement undertaken through primary grassroots cooperatives. 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 fertilisers and chemicals.

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Table 1. Existing ICT techniques in Kamwezi subcounty, Kabale District, SW Uganda

No.	*Practice*	*Where Used*	*Soil Conserv.*	*Main Purpose* *Water Conserv.*	*Fertility Improv.*	*Other Purpose*
S	STRUCTURAL					
S1	Trash lines (TL)	Slopes, Annual Crops	1	3	2	
S2	Ridges (R)	Slopes and flat areas for Irish and Sweet Potatoes	3	2	1	Increases soil volume for tubers
A	AGRONOMIC					
A1	Mulching	Bananas, Tomatoes, Coffee, Pineapples	3	1	2	Weed control
A2	Crop Rotation (CR)	All Annual Crops	-	-	1	Pests/Disease control
A3	Burying Weeds and Trash	All crops	-	2	1	Weed Control
A4	Trash Heaping	On flat land and between TL. on slopes	2	3	1	Clean fields

S = Structural/Physical Measures
A = Agronomic/Cultural Practices
TL = Trashline

Source: Miiro et al. (1996)

2.4 Farming systems

Agriculture is entirely based on smallholder production with farm size varying from a minimum of 1 ha to over 12 ha. Crops are grown alone or mixed nearly always using *ngoro* except on the flat where intricate drainage systems are seen. The season starts with the onset of the rains in November or December when maize and cassava are planted, with a second planting in April or May for crops such as beans, wheat, potatoes and peas which grow on residual moisture. The most common crop rotation on *ngoro* is beans with some planting of cassava followed by maize. Some farmers keep the *ngoro* and ridge systems completely separate. Others convert from ridges to *ngoro* when fertility declines.

Most manure is used close to the homestead on coffee, fruit trees and occasionally maize. Due to the low numbers of livestock in the area manure is always in short supply. Most farmers apply nitrogenous fertilisers (CAN-27%N, SA-21%N or urea-46%N) to their coffee crops, occasionally to maize but never to other crops. Mulching of coffee is recommended and commonly carried out with material from nearby fields or from the leaves of *Grevellia robusta* which is common as a shade tree for coffee.

2.4.1 ICT Systems

All soil preparation is undertaken by hand using either the *ngoro* system or one of two types of ridges: with or without plant residue incorporated. Flat cultivation occurs only in the valley bottoms.

The most conspicuous and original feature of agriculture in the area is the *ngoro* system. *Ngoro* are used almost exclusively for food crops within a slope range of 10% to 60%. However, it is dependent on fallow period the minimum of which is 6-8 months. The length of fallow in the rotation varies according to population and cropping intensity. As population intensity increases, fallow decreases in terms of both duration and percentage of total land use. In the highest population areas fallow is rarely found. Table 4 indicates the periods of cultivation and fallow in each zone.

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Table 2. Summary of Indigenous Conservation Tillage (ICT) systems in East Africa

Country	*Region*	*Rainfall (mm)*	*Indigenous conservation tillage techniques*	*Major crops*	*Reference*
Kenya	Mbeere District, Rift Valley Province	650+	Trashlines, loglines, stone bunds across slopes	Maize, sorghum, millet	Altshul and Okoba (1996)
	Kenya Highlands	1000+	Retention ditches	Coffee, bananas	Thomas and Biamah (1991)
Tanzania	Ukara Islands, Lake Victoria	1500	Earth and stone terraces, tied-ridging, stone barriers in gullies (FWH), mount cropping	Maize, millet, rice, cassava, vegetables	Allan (1965)
	Southern Highlands	1000-1500	Ridges (with-and-without incorporation of organic residues)	Maize, beans, wheat, peas, sweet potatoes, round potatoes	BACAS (1993)
	Mwanza and Shinyanga Regions	750-1000	Tied-ridging, *majaruba* system (i.e.cultivated bunded basins)	Maize, rice, sorghum, millet, groundnuts	Allnut (1942) Prentice (1946) Mwakalila and Hatibu (1992) Kayombo (1993)
	Dodoma, Singida and Tabora Regions	600-800	*Majaruba* system (i.e. cultivated bunded basins)	Rice	Allnut (1942) Mwakalila and Hatibu (1992)
	Iringa Region		*Vinyungu* (i.e. camber-bed type of cultivation)	Maize, beans, peas, vegetables	BACAS (1997)
	Uluguru Mountains, Morogoro Region	1000-1500	Ladder terraces (i.e. trash contour ridges)	Vegetables	Temple (1972)
	Mbinga District, Southwest Tanzania	1500	*Ngoro* (i.e. Matengo pip system), ridges (with-and-without incorporation of organic residues)	Maize, beans, wheat, cassava	Allan (1965) Kayombo and Dihenga (1993)
	Kabale District, Southwest Uganda	1000	Trashlines, banana mulching, ridges	Bananas, round and sweet potatoes, sorghum	Miiro et al. (1996)
Uganda		800-1000			

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Table 3. 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 slopes 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 with mountains	66%
	South	1200	1000-1200	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%

Source – PRA report (Ellis-Jones et al. 1994).

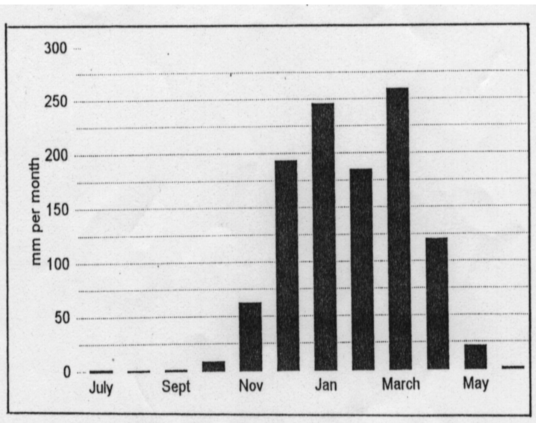

Figure 1: Average monthly rainfall

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 2-2.5 metres. After dying 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 a 6-8 month short fallow.

They are reformed in the same way, but this time laying the grass lines across the

centre of the existing pits and bunds. Soil is dug from the existing bunds and placed over the grass to form new bunds. Thus, what was previously a pit becomes a bund and vice versa. Burning on *ngoro* was rare but is now increasing to reduce crop residue and labour 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 DALDO staff on the relative use of ngoro and ridges on food crops are shown on Table 5.

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Table 4. Average duration of cultivation and fallow in the Highlands (years)

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

Source: Derived from ICRA (1991)

Table 5. The extent of ngoro and ridges (% of land under cultivation)

LAND PREPN SYSTEM	*HIGHLANDS (Mountains and Plateau)*	*LOWLANDS North*	*South*
Ngoro	95	70	30
Ridges	5	30	70

There are basically two types of ridging, one with organic matter incorporated and one where organic matter is burnt off first. When the ridges are reformed the following year, grass is cut and laid 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*. Ridges with no incorporation of plant residue are formed in a similar way to the ones described above.

There is a fairly clear division of labour 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 ridges 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 almost always kept by men. Women retain income from sale of maize and beans unless there is no coffee, when men retain this as well.

2.4.2 Farmers' perceptions and evaluation criteria

Two separate workshops were held with the participating farmers and local leaders to establish within a group forum farmers views and their evaluation criteria on the comparative advantages of *ngoro* and ridges. The main conclusions emerging are shown in Table 6.

All groups regarded Ngoro as the best ICT practice. Farmers' views confirmed that the most important benefits of ngoro are erosion control, moisture retention and fertility maintenance. Important also is the fact that higher yields are achieved in comparison to ridges when no fertiliser is applied, April planted bean yields are higher and land preparation is only undertaken once every two years.

About the ridges, the view was that they can be as effective as *ngoro* when properly constructed and organic matter is incorporated. They require less labour and give higher yields when fertiliser is used.

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Table 6. Benefits of *ngoro* and ridges

NGORO Benefits	Ranking	***RIDGES*** Benefits	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 labour than ngoro	2
Retains fertility better when no Fertiliser is applied	3	Give higher yields than ngoro when fertiliser is Applied	3
Gives higher yields than ridges When no fertiliser 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	6	Easier to plant than ngoro (using proper spacing)	6
Made every two years	7	Best for beans planted in December	7
Cassava can be grown on ngoro	8	Easier to fertilise than ngoro/uses less fertiliser	8
Traditional system	9	Easier to employ people to construct	9
Helps people not to migrate	10	Easier to mechanise	10

Other important benefits were that men and women shared the work and that ridges were better for inter-cropping. As for the criteria on choice of either *ngoro* or ridges, control of soil erosion, labour availability and having the finance available to buy fertiliser ranked highest in deciding the ICT measure to use.

In considering whether *ngoro* would increase or decrease in the future, farmers were split almost 50:50 in the views.

2.4.3 Economic analysis

As a result of discussion with farmers on an individual and group basis as well as measurements being recorded in the field, the comparative labour requirements of *ngoro* and ridges have been determined. Field measurements and information based on individual discussions were similar and indicated nearly 20% less labour for ridges. Burning allowed labour to be reduced by nearly 50%. This is shown in Table.7. This confirmed that *ngoro* is most labour intensive conservation technology followed closely by ridges with organic matter incorporated. It is for this reason that farmers seek methods to reduce the labour input associated with *ngoro*. Examples include: reducing the organic matter within the *ngoro* through burning excess grass and laying the grass in parallel lines. All costs, except those associated with the purchase of hoes and sickles comprised labour which was in most cases provided by the family. When people hired labour it was for ridge construction as hired labour is regarded as untrained for *ngoro* construction.

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Table 7. Labour requirements for ngoro and ridge cropping systems (days per ha)[3]

	NGORO		*RIDGES*					
			With organic matter			*Without organic matter*		
Planting date	*Maize Dec*	*Beans Apr.*	*Maize Dec*	*Beans Apr.*	*Beans Dec.*	*Maize Dec.*	*Beans Apr.*	*Beans Dec.*
Burning	0	0	0	0	0	1	1	1
Slashing	5	10	5	10	10	0	0	0
Arranging grass	0	13	0	13	8	0	0	0
Pitting or 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	13	8	13	8	13	10	5	10
Total	**60**	**70**	**58**	**50**	**65**	**48**	**22**	**41**
% labour for April ngoro	***85%***	***100%***	***82%***	***71%***	***92%***	***71%***	***36%***	***61%***
% labour for two crop system	***100%***		***83%***			***54%***		

Considerable variation in crop yields occurs depending on altitude, rainfall, fertiliser use and other management factors. Typical yields have been obtained through discussion with DALDO extension staff and local farmers as well as from measurements. These are shown in Table 8.

Table 8. Typical yields and ranges for the main crops (kg per ha)

		MAIZE	*BEANS*		
LAND PREPARATION SYSTEM	*FERTILIZER APPLICATION*	*YIELD (kg/ha)*	*FERTILIZER APPLICATION*	*April (kg/ha)*	*December (kg/ha)*
Ngoro	Basal and topdressing	4000	Basal	500	
	Topdressing only	1500	None	300	
Ridges with organic matter	Basal and topdressing	4000	Basal	400	500
	Topdressing only	1000	None	200	300
Ridges without organic matter	Basal and topdressing	3500	Basal	300	400
	Topdressing only	500	None	150	300

Trials in the 1940s (Berry and Townsend, 1972) confirmed that ngoro maize yields were higher compared to tied ridging or flat cultivation. Trials in the 1950s (Allan, 1965) confirmed this indicating however that the difference was not great except in exceptionally wet years. Yields on ngoro are said by most farmers to be considerably greater than those on ridges when fertiliser is not used. When fertiliser is used at recommended rates, little difference in yield results. Gross-margins detailing returns to land, capital and labour have been calculated in order to compare the relative productivity of ngoro and ridges. These have been based on two levels of production:

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Table 9. Gross margin analysis based on high input practices (DALDO recommendations)

CROP	ICT METHOD	YIELD	INPUTS			RETURNS		RANK
		(kg/ha)	**Labour** *(day/ha)*	**Cash** *(Tsh)*	**Land** *(Tsh/ha)*	**Cash** *(%)*	**Labour** *(Tsh/day)*	
Maize	Ngoro	4000	60	112750	107250	248%	2788	2
	Ridges with organic matter	4000	58	112750	109750	248%	2909	1
	Ridges without organic matter	3500	50	112750	84750	222%	2695	3
Beans (planted April)	Ngoro	500	70	32500	72500	538%	2036	2
	Ridges with organic matter	500	50	32500	92500	538%	2850	1
	Ridges without organic matter	200	25	31000	14000	226%	1560	3
Beans (planted December)	Ngoro	-	-	-	-	-	-	-
	Ridges with organic matter	500	65	32500	77500	538%	2192	2
	Ridges without organic matter	400	43	32500	65500	438%	2541	1
Maize and beans (two crop system)	Ngoro		130	145250	179750	393%	2412	2
	Ridges with organic matter		108	145250	202250	393%	2879	1
	Ridges without organic matter		75	145250	98750	224%	2128	3

Table 10.Gross margin analysis based on lower input practices

CROP	ICT METHOD	YIELD	INPUTS			RETURNS		RANK
		(kg/ha)	**Labour** *(day/ha)*	**Cash** *(Tsh)*	**Land** *(Tsh/ha)*	**Cash** *(%)*	**Labour** *(Tsh/day)*	
Maize	Ngoro	1500	60	28600	21400	367%	1389	1
	Ridges with organic matter	1000	58	27000	-9500	259%	819	2
	Ridges without organic matter	500	50	23600	-36100	148%	240	3
Beans (planted April)	Ngoro	300	70	12000	28000	875%	1431	2
	Ridges with organic matter	200	50	11500	13500	609%	1300	3
	Ridges without organic matter	150	25	11250	18750	467%	1833	1
Beans (December)	Ngoro	-	-	-	-	-	-	-
	Ridges with organic matter	400	65	12500	70000	1120%	2217	2
	Ridges without organic matter	300	43	12500	55500	875%	2480	1
Maize and beans	Ngoro		130	40600	49400	621%	1410	1
	Ridges with organic matter		108	38500	4000	434%	1060	2
	Ridges without organic matter		75	34850	-17350	307%	1037	3
Maize and beans (mixed crop)	Ridges with organic matter		53	4850	16150	1515%	1308	1
	Maize	300						
	Beans	150						
	Ridges without organic matter		48	4350	-11600	925%	756	2
	Maize	200						
	Beans	75						

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- A high input level based on the use of hybrid seeds, fertiliser and pesticides as recommended by DALDO (Table 9).

- A lower input level where local seed varieties, small amounts of fertiliser (topdressing only) and minimum pesticides (Table 10) are used.

All participating farmers used the lower input system.

The resulting gross margins present two conclusions:

- In high input systems, ridges incorporating organic matter and requiring lower labour input provide best returns to land and labour for both maize and April beans. Burning crop residues, although saving labour, results in lower yields and lower returns to land for all crops. However, December beans show greater returns to labour indicating the attractiveness of burying and as labour prices rise burning becomes increasingly attractive from a short term economic stand point.

- In low input systems, however, the traditional ngoro outperforms ridges despite the increased labour requirement. Returns to land, cash and labour are higher when comparing the system over both a maize and a bean crop. However, the results show burning, again, to be attractive, especially for both April and December beans. Despite achieving lower yields, the reduced labour requirement makes returns to labour attractive in the short term.

In comparing the two sets of results returns to land and labour attractive in the short term. In comparing the two sets of results returns to land and labour are significantly less for low input systems, but returns to cash (capital) are significantly greater.

While capital is scarce and labour is plentiful it is rational to use the lower input systems based on *ngoro* which provides the greatest returns.

A major concern must be the attractiveness of burning and the long-term degradation that will result. The challenge is therefore to identify methods of reducing the labour requirements for *ngoro* and ridges as well as low cost yield increasing technologies that maintain the conservation advantages of both *ngoro* and ridges.

2.4.4 Technical evaluation

Three sites were selected in March 1995. The following ICT methods were investigated:

i) Ngoro (N)
ii) Ridges with incorporated organic residues (R+OR)
iii) Ridges with no incorporated organic residues (R-OR)

All three methods were investigated at the three sites described in Table 11. At each site the three ICT treatments, each measuring 22x60m, lay side by side, separated by tied ridges and with a cut off drain at the top and bottom. Each field had previously been under fallow and was formed and planted with beans in April 1995, harvested in June 1995, and then weeded and planted with maize after the first rains in December 1995 which was harvested in July 1996.

Table 11. Field descriptions

Area	Slope (%)	Average *Ngoro* dimensions (m)	Average ridge spacing (m)	Previous fallow period (years)
Lipumba	15	2.30x2.37	1.12	1
Lipumba	45	2.60x2.25	1.00	4
Mhekela	40	2.33x2.06	1.41	1

2.4.5 Technical investigations

Climatic monitoring was carried out through a manual raingauge installed at each site in November 1994. Organic Carbon percent (%C) and total N (%N) content were determined in all fields using core samples taken at 0-5 cm increments down to 20cm depth. Samples were also collected every two weeks from newly formed *ngoro* and analysed for % C and %N to investigate

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the extent and duration of nitrate depression. Ngoro length, width, depth, and growing area on each bund, was recorded on 15 newly formed *ngoros* in each of three fields in each of three slope classes (2-10%, 15-25% and >40%) at each of Mhekela and Limpumba sites. Length and width of 10 *ngoros* in each of a further 11 fields was also noted and 50 holes augured to investigate the extent of buried residues.

In May 1995, exploratory soil moisture measurements were taken with a Speedy Moisture (calcium carbide) Meter in all trial fields under beans at Mhekela, 22 days after the last rainfall. In November 1995, 54 neutron probe tubes were installed. The probe was calibrated for each site and weekly measurements taken since. On *ngoro*, one tube was installed in the centre of the bottom bund, the centre of the side bund and in each bottom corner, of 3 *ngoros*. Three tubes were installed in all ridged fields and one calibration tube per site. Monthly soil surface profiles were recorded down the slope during the rainy season using a locally manufactured Soil Surface Profile Gauge. Profiles were also taken across the slope through several *ngoro*. To investigate the volume of soil moved in ridges compared to *ngoro*, profiles were taken before and after formation of each.

Plants were counted in three areas of each field to estimate plant populations. Plant height and number of leaves were measured weekly. The growing area per hectare in each field was calculated and all yields recorded. Maize yield from the side bund of *ngoro*'s was compared to that from the bottom bund.

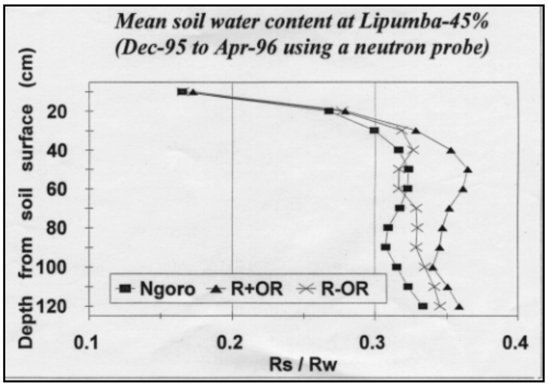

Figure 2a: Mean seasonal soils moisture content (December 1995-April 1996) at Lipumba -45%

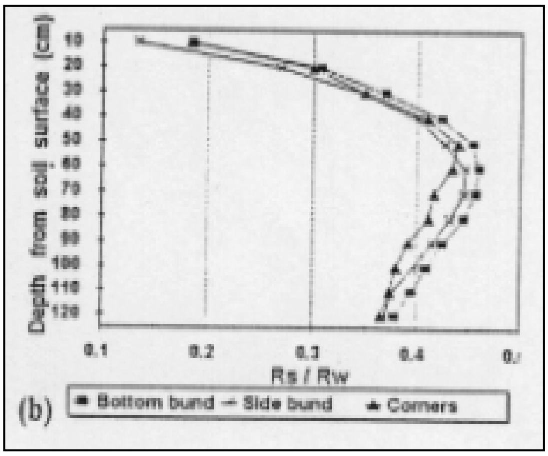

Figure 2b: Mean seasonal soils moisture content (December 1995-April 1996) Around 3 ngoros at Lipumba -15%

3. Results and discussions

Rainfall at Lipumba during 1994/95 season was 958 mm compared to 1030 mm at Mhekela village, increasing to 1080 and 1218 mm respectively during 1995/96.

Ngoro's are generally larger than the historically quoted (1.5m^2). Average dimensions, measured in April 1996 at Mhekela, where *ngoro* has a long history, were 2.36x2.08m (aligned downslope) varying from 1 to over 3 m. At lipumba, where *ngoro* is relatively new, the pits were slightly smaller and more rectangular (2.31x1.95m). On gentle slopes *ngoro*'s tend to be more square with the actual pit often being round, but as slope increases, they become longer and thinner, usually aligned downslope. These findings confirm that farmers are beginning to abandon tradition in favour of easier options, especially at Lipumba.

Within recent years, many farmers have also stopped laying the grass into a matrix, in preparation for *ngoro* construction. Instead they only lay it into parallel lines running downslope. This means that the fertility of the top/bottom bunds, in the absence of buried residues, will decrease. Soil erodibility may also increase as it is these smaller bunds which are subjected to the strongest erosional forces and whose continued existence dictates the effectiveness of the pits, in terms of both soil and water conservation.

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Table 12. Variation in pit depth with slope

Slope Class (%)	*Depth Range (cm)*	*Average Depth cm*
2-10	22-40	30
15-25	8-36	21
>40	5-2	14

Table 12 shows the average depth to decrease from 30cm on gentle slopes, through 21cm on average slopes, to 14cm on steep slopes. Depth also decreases throughout the season as the pit becomes filled with plant residue thrown into it and with soil eroded from the surrounding ridges.

Soil moisture measurements using the neutron probe (Rs/Rw values) taken from December 1995 to April 1996 showed that ridges retained more moisture than *ngoro*. R+OR (ridges plus organic residues) and R-OR (ridges less organic residues) retained the most moisture at Lipumba-45% and Lipumba-15% respectively (Figure 2a). In both cases *ngoro* retained the least. The *ngoro* bottom bund (BB) retained more moisture than the side bund (SB) from 0-40 cm at Lipumba-45% and at all depths at Lipumba-15% (Figure 2b), presumably as a result of water pooling above the BB. At all sites, the corners generally retained the least moisture.

Results obtained from the calcium carbide meter taken in May 1995 showed different trends. The *ngoro* at Mhekela, had more moisture than the ridges, especially below 15cm. These were the most important results as beans are grown at this time on residual soil moisture. Neutron probe values were taken whilst maize was growing, from December to July, when there was little water stress. Moisture reached a maximum at 15cm which corresponded with the centre of the organic layer and this was presumably due to the organic residues causing an increase in the soils water holding capacity.

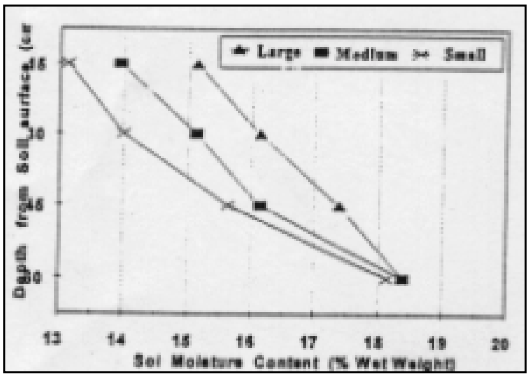

Figure 3a: Soils moisture mesured on Ngoros under beans: large (3x2.5m), medium (2.5x2m) and small (2x1.5m) ngoros

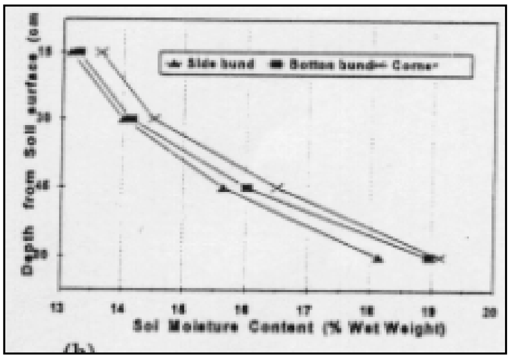

Figure 3b: Soils moisture mesured on Ngoros under beans: on various bunds of small (2x1.5m) ngoros

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Table 13. Plant populations per hectare

	Ngoro	*R+OR*	*R-OR*
Lipumba-45%	34,200	24,200	21,900
Lipumba-15%	30,900	16,000	23,200
Mhekela	23,500	20,700	20,800

Soil moisture content in the side bunds clearly increased with pit size (Figure 3a). The effect was less clear on the bottom bunds and corners. Overall the corners retained the most water and side bunds the least. This was especially clear in the smallest pits (Figure 3b).

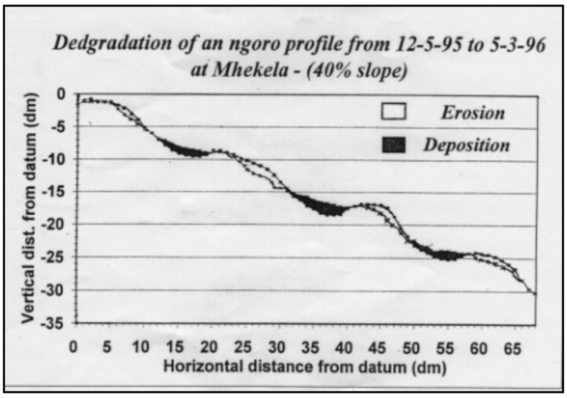

Figure 4. Soil distribution in Ngoro at Mhekela from May 1995 to March 1996

Soil surface profiles taken in the period May 1995 to March 1996 showed that the majority of *ngoro*'s and ridges had degraded into flat or gently sloping terraces (Figure 4). The amount of deposited sediment in pits of a *ngoro* field is large (Figure 4). In the ridged fields, however, the degree of decomposition in the furrows was small, suggesting that some soil is transported elsewhere.

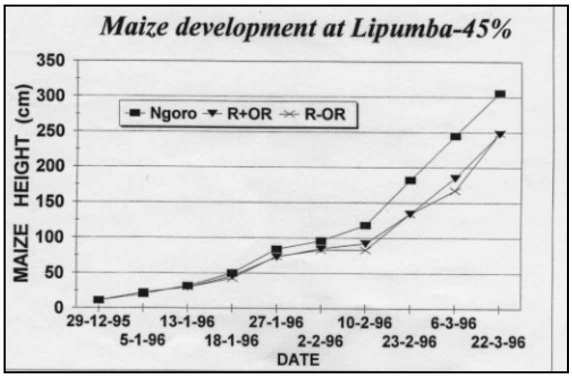

Figure 5. Maize development at Lipumba - (45%)

At Lipumba all fields had similar initial maize growth rates (Figure 5), but by end of January 1996, the *ngoro* had taken a clear lead. The two ridged fields had similar values with R+OR being slightly better. Similar plant growth trends were observed at Mhekela although this site suffered the most past erosion.

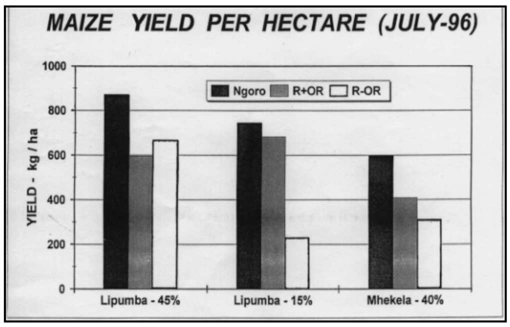

Figure 6. Maize yields (kg/ha) July 1996

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Table 13. Shows the *ngoro* to have more plants per ha at all sites. The differences are most apparent at Lipumba-45% where 3 rows were planted on the SB's, and Lipumba-15%, with two rows, compared to just one row at Mhekela.

The rains finished early in May 1995, so bean yields were very low, with no harvest from Lipumba-15%. Table 14 shows that *ngoro* produced superior yields. It appears therefore, that when under severe stress, *ngoro* may make the difference between something and nothing. The higher yields on R-OR at Mhekela are presumably due to this field having higher initial nitrogen levels.

Figure 6 shows quite clearly that the *ngoro* produced the highest maize yields in all three fields harvested in July 1996. The yield per plant was lower on *ngoro*, due to an increased competition for resources between higher number of plants (Table 13) but this is an acceptable sacrifice.

Table.14. Bean yields (kg/ha)-June 1995

	Lipumba-45%	*Mhekela-40%*
Ngoro	82	133
R+OR	44	89
R-OR	44	133

4. Conclusions

ICT techniques in East Africa are prevalent in areas of water-deficit conditions and in semi-arid zones. These techniques have survived through several generations as a result of a combination of factors, among them:

- the realisation of moisture conservation to overcome moisture scarcity as a crop production constraint,
- the historical obligation to produce crops on hillsides and steep mountain slopes with thin topsoil layers,
- population pressure and
- the influence of land tenure.

Due to changing natural and socio-economic environment, some of these ICT systems are beginning to show signs of decline. The need to understand these systems is a first step towards their improvement.

The socio-economic evaluation of ICT techniques in Mbinga District of SW Tanzania has shown that *ngoro* cultivation is efficient at controlling soil erosion, increasing soil moisture at critical times of the year and maintaining soil fertility. The problems associated with it, notably decreasing fallow periods and high labour requirement, indicate declining use, except at the traditional centre of the *ngoro*.

The technical evaluation has shown that compared to ridges, when *ngoro*s are intact, they increase soil moisture and consequently bean yields. When badly degraded, soil moisture is decreased but despite this, maize growth and yields are better than on ridges, when no fertiliser is used. In *ngoro*, the majority of eroded soil is redeposited into the pit, whereas on ridges it is often transported elsewhere.

The immediate future challenge is to build productivity enhancing improvements into the present system without destroying its unique advantages.

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