Component Analysis of Farming Systems With Relevance to Finger Millet Cultivation in South Western Tanzania

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Abstract

Interpretation of farming systems involves many aspects influencing the systems. Different components of farming systems have been categorized as cropping systems, the farm household system, livestock system and the interaction between these components and the environment. The purpose of this paper is to preface component analysis results of a study of finger millet farming systems of South Western Tanzania. The farming systems in the area fall mainly in two categories namely shifting cultivation and fallow systems. These systems are characterized by specific cultivation systems such as slash-and-burn, mounds (ntumba) and "burnt mounds" (nkule), ridge cultivation and various forms of ox-ploughing. Finger millet is sown mainly as a mono-crop usually with insignificant intercropping tendencies. The crop is cultivated essentially for cash. Farm households with cattle are better cultivators of the crop. Households practicing ox-ploughing were mostly those who owned more cattle and were cultivating greater acreages. Having more wives increased household size and workforce and these were very important sources of household's manpower. Availability of good and reliable markets and good transport logistics are important constraints limiting the crop production. There is also need to investigate further on the scientific and environmental parameters responsible for sustainance of the traditional systems that predominate the crop production.

Key words: Farming systems, Component analysis, Shifting cultivation, Fallow systems, Mono-crop.

Introduction

Farming systems, according to ICRISAT (1974), is defined as "the overall complex of development, management and allocation of resources as well as decisions and activities that within an operational farm unit or combination of such units results in agricultural production and the processing, marketing (and utilization) of the products". It is obvious from this definition (also agrees with other (Norman, 1979; Turner and Brush, 1987; Beets, 1990) definitions) that farming systems is a complex, multidimensional concept and its interpretation involves many aspects influencing the system.

A system is an entity with components that interact with each other. Farming systems likewise is comprised of different components. Fresco (1986) categorizes the different components as cropping systems (or sub-system), the farm household system, livestock system; and the interaction between these components and the environment (social, biological, physical). The interaction among components and between components and the environment can be conveniently recognized as socio-economic and environmental component.

The different components of farming systems as categorized by Fresco (1986) are universal regardless of type of farming system. Land use pattern is an important consideration in farming systems analysis as it describes the behaviour of resource management and allocation of farm activities. Among land use pattern

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interpretations include cropping (or crop) systems and cropping cycles, cultivation systems or land preparation techniques and aspects of allocation of land to different farm activities. Livestock system is an integral part of land use pattern and when proper interactions are operating between livestock system, cropping system, the household system and the social and physical environment systems a farming system exists as a single operational entity. Fig. 1 clarifies more on components or subsystems and interactions in a typical farming system. The paper further describes the activities and management aspects of the finger millet farming systems in South Western Tanzania based on cropping, livestock, household and the socio-economic and environmental components of the system.

Materials and methods

The information has been obtained as a result of research conducted in years 2000, 2001 and 2002 on the crop farming systems. The research involved survey conducted in Mbozi and Ileje Districts in Mbeya Region and in Sumbawanga and Nkasi Districts in Rukwa Region. The two Regions, extend from 7° – 9°40'S and 30°15' – 33°45'E and are good representatives of South Western Tanzania. In this area finger millet is a very important crop. In most of the area it is the only exclusively cash crop. The survey was conducted to collect information on characteristics of finger millet farming systems. This survey enabled distinguishing important descriptions of shifting cultivation and fallow (also continuous cultivation) farming systems based on intensity of rotation, (R) (Ruthenberg, 1979), which is requisite baseline information for component analysis of the systems. According to intensity of rotation criterion (the percentage of time when a land area is under cultivation against length of fallow for the same piece of land) a system is recognized as shifting cultivation when $R \leq 33.3\%$(two thirds of length of cycle of land utilization is fallow) and as fallow system when length of cultivation is more than a third of the length of cycle of land utilization but not exceeding two thirds ($33.3\% \leq R \leq 66.7\%$). Continuous cultivation is when length of fallow is less than a third of cycle of land utilization.

Results and discussion

Cultivation systems

During this research the slash and burn, the Fipa mounds or *ntumba*, "burnt mounds" or *nkule*, ox-ploughing and ridge cultivation systems were encountered as important reference points for the finger millet crop farming systems. These systems of cultivation are described in much more detail in Msuya (2003). The slash and burn, *nkule* and *ntumba* systems have been categorized as belonging to shifting cultivation farming system; ox-ploughing partly belongs to shifting cultivation (long-fallow), partly to fallow system and sometimes continuous cultivation (rotational fallow). The ridge system was categorized as totally belonging to fallow system and sometimes continuous cultivation (rotational ridges). Ox-ploughing is usually practiced as cultivated fallow or *kuvundika* (Msuya, 2003) where the field is cultivated during the rainy season but not planted with any crop until the next rainy season; or as *nsindeulale* where a long or short fallow field is cultivated at the beginning of rains (un-cultivated fallow) and sown immediately. Cultivated fallow ridge system also exists. More details on cultivation and fallow periods in relation to the farming systems identified during this research are presented in Table 1.

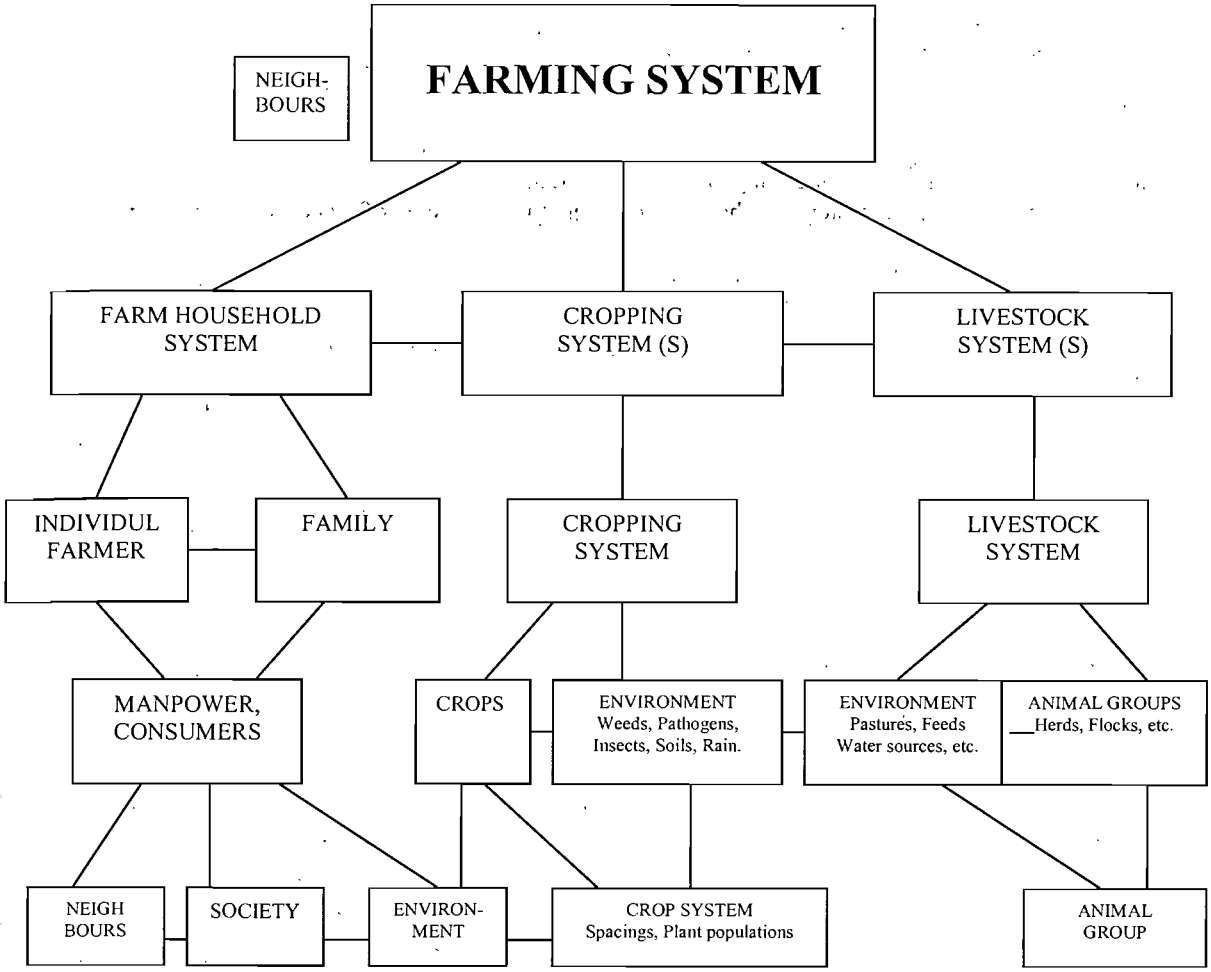


Fig. 1. Conceptual model of farming systems (Modification from original illustration extracted from Fresco (1986)

Table 1. Classification of farming and cultivation systems under which finger millet is been produced in South Western Tanzania

Cultivation system	Years of cultivation		Years of	Respective farming	Vegetation
	Millet	Other crops	fallow	system	
Slash and burn	1-3	3-5	15-40	Shifting cultivation	Woodland
Ntumba	1-2	3-5	10-15	Shifting cultivation	Woodland
	1-2	3-5	3-5	Fallow	Grassland
Nkule	1	0	4-5	Shifting cultivation	Grassland
	1	1-4	5-10	Shifting cultivation	Grassland
Ox-plough long fallow					
Cultivated fallow	1-2	3-5	10-15	Shifting cultivation	Woodland
Nsindeulale	1-2	3-5	10-15	Shifting cultivation	Woodland
Ox-plough short fallow					
Cultivated fallow	1-2	3-4	2-6	Fallow	Grassland
Nsindeulale	1	3-4	2-6	Fallow	Grassland
Ridges					
Cultivated fallow	1	2-4	2-5	Fallow	Grassland
Uncultivated fallow	1	2-4	2-5	Fallow	Grassland
Rotational ox-ploughing	1	2-5	1-2	Continuous	Grassland
Rotational ridges	1	2-5	1-2	Continuous	Grassland

Classification based on intensity of rotation, R.
R calculated from upper or lower limits (not combination) of the time periods under cultivation or fallow

Component analysis

Cropping and Cropping Systems

Cropping systems and the whole chain of activities from sowing to harvest comprise very important distinguishing characteristics of finger millet farming systems. These depend partly on method of land preparation and synchronization of field crop management practices.

In South Western Tanzania regardless of method of land preparation, finger millet is planted by broadcasting. The soil must be well broken or without large soil clods to allow proper seedling emergence. After broadcasting the seed is usually lightly covered with soil to prevent exposure to birds and sun. Because of broadcasting there is no definite spacing for the crop; it only needs expertise in broadcasting to ensure uniform distribution of seeds and prevent overcrowding when the seedlings emerge. Usually during broadcasting the older members of household or those best trained or experienced are the ones involved. They hold the seed with closed fingers except the finger nearest to the thumb and with the thumb in-between the two fingers nearest to it. With release control of the thumb the farmer throws the seed horizontally in left and right directions as he/she moves forward slowly but straight, so that a small quantity of seed is allowed to fall on the ground evenly, resulting in uniform but not too densely populated crop when seedlings emerge and establish in the field. Overpopulation or poor crop stand in the field are reasons for severely reduced yields.

In shifting cultivation and fallow systems where finger millet is involved the crop is planted as an opening crop when cultivation resumes in the fallow or virgin land. Rarely is finger millet planting repeated in the same field after harvesting finger millet as the first crop. This is, according to farmers, because yield declines with repeated cropping. In these systems, of course, there is no use of chemical fertilizers and the first crop harvest will have depleted most of the natural soil fertility retained during the fallow period or boosted up by burning.

In most situations finger millet is planted as a mono-crop with very sparing intercropping,

mostly with maize and sorghum, sometimes with sunflower, simsim and pigeon peas. In these intercrops the companion crops are of no significance in land equivalent ratio analysis. They are sometimes nutured in the field as volunteer crops arising from accidental seed mixtures. Nevertheless they are harvested as minor food sources.

In burnt mounds or *nkule* system it is usual for finger millet to be inter-cropped with irish potatoes which are planted in the mounds before they are broken and soil spread for finger millet sowing, thus growing in those localized positions. The irish potato crop usually grows fast and is harvested normally before flowering of the finger millet crop. Both finger millet and irish potatoes grow vigorously and luxuriously in the localized areas because of high fertility and very clean, weed and pathogen-free soil.

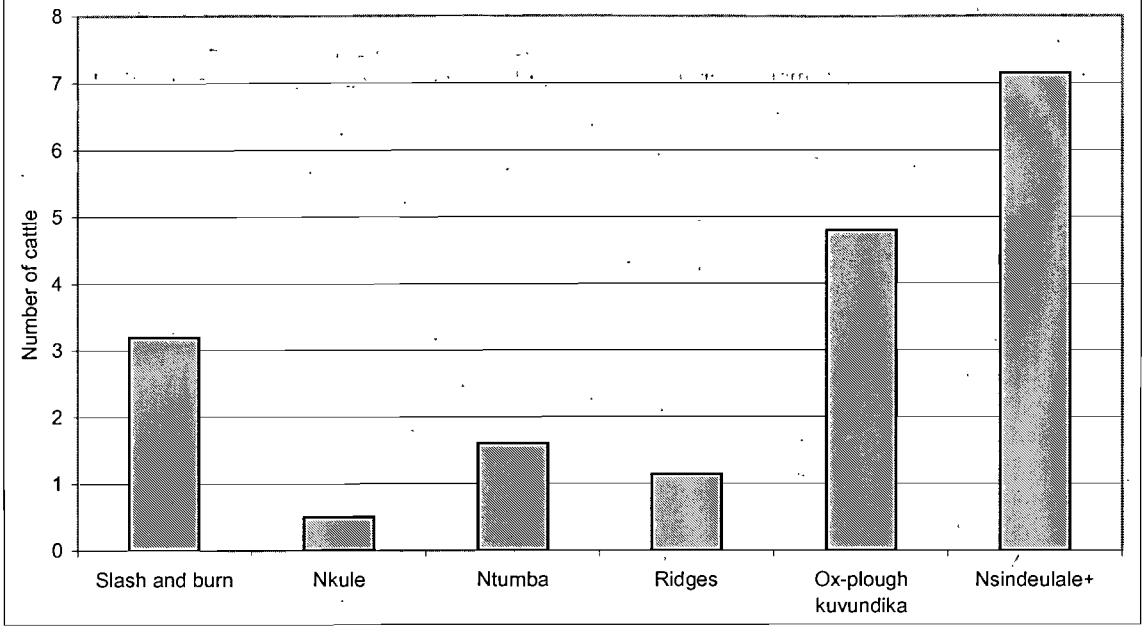
In the ridge system the proportion of the companion crop is sometimes high especially when millet and cassava are planted. When ridges are made sometimes as rains begin maize is planted in November on the sides of the ridges without breaking them. The maize crop grows and in late December which is the normal time for finger millet sowing the ridges are broken while weeding maize, soil is levelled and finger millet broadcasted. In this system finger millet is still the major crop but the population of maize crop is significant, roughly not less than 25%. Sometimes the ridges are not cultivated fallow ridges but those where a previous season crop like beans has been harvested. These ridges remain intact and in November they are surface-cleared and maize planted. Later on during weeding the maize crop the ridges are broken, soil leveled and finger millet seed broadcasted. In this system usually finger millet is minor crop, maize population is optimum and often the finger millet crop harvested is very insignificant.

Where cassava is the companion crop it is usually planted immediately after making the cultivated fallow ridges in March/April towards the end of the rainy season; they then become the cultivated fallow crop until the next rainy season when the ridges are broken in late December/January and finger millet planted. Here again usually cassava is the main crop and because of shading effect of the cassava crop finger millet does not occasionally perform very well.

Livestock and Finger Millet Cultivation in South Western Tanzania

In specific situations evolution of finger millet farming systems in South Western Tanzania is very much associated with livestock (cattle) keeping. This is particularly so in Rukwa Region where the predominant system is ox-ploughing fallow system. In other places also farmers practicing ox-ploughing are also livestock keepers. Figure 2 and 3 show cultivation (land preparation) and livestock keeping characteristics of finger millet farmers in Mbozi District. It was found that among the farmers those practicing ox-ploughing had the most numbers of cattle (Fig. 2). Least number of cattle were owned by farmers practicing *nkule*, ridge and *ntumba* systems of cultivation. In these systems more than 50% of farmers interviewed did not have cattle. This is illustrated in Fig. 3. In the *nkule* system as many as more than 70% of the farmers were having no cattle. It was farmers that were practicing ox-ploughing that were leading in both possession and having more cattle.

Fig. 2. Possession of cattle in relation to system of cultivation among finger millet farmers in Mbozi District



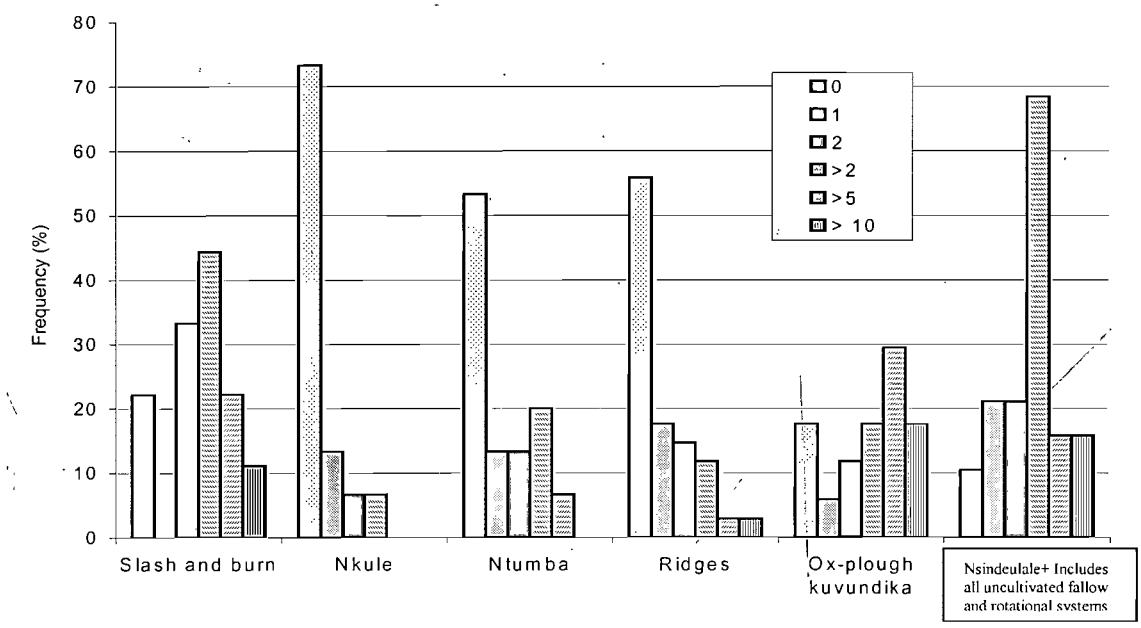


Fig. 3. Frequency distribution (percentages) of number of cattle in relation with method of cultivation among finger millet farmers in Mbozi District.

Fig. 4 shows the relationship between acreage and number of cattle that ox-ploughing finger millet and maize farmers possessed. Regardless of system of ox-ploughing, there was tendency of number of cattle increasing with acreage for those farmers who had cattle. There were few exceptions for example with maize acreage for farmers who practice rotational (and fallow system uncultivated fallow) cultivation. With these farmers number of cattle more than two up to 10 herds or more was associated with progressively decreasing acreage. Acreage for farmers without cattle did not follow the overall trend, it was in most situations more than acreage for farmers with at least two herds of cattle except in ox-plough *kuvundika* system. The farmers who do not have cattle usually borrow or hire oxen from other farmers. Especially because it is costly to hire oxen those farmers must cultivate considerablyas much acreage as it can profitably compensate the cost. The increasing acreage trend with increasing number of cattle was more determinate with finger millet than with maize or a combination of maize and finger millet acreages. In the ox-plough *kuvundika* system acreage increased with number of cattle up to when farmers had more than 5 cattle but not up to when they had more than 10 cattle.

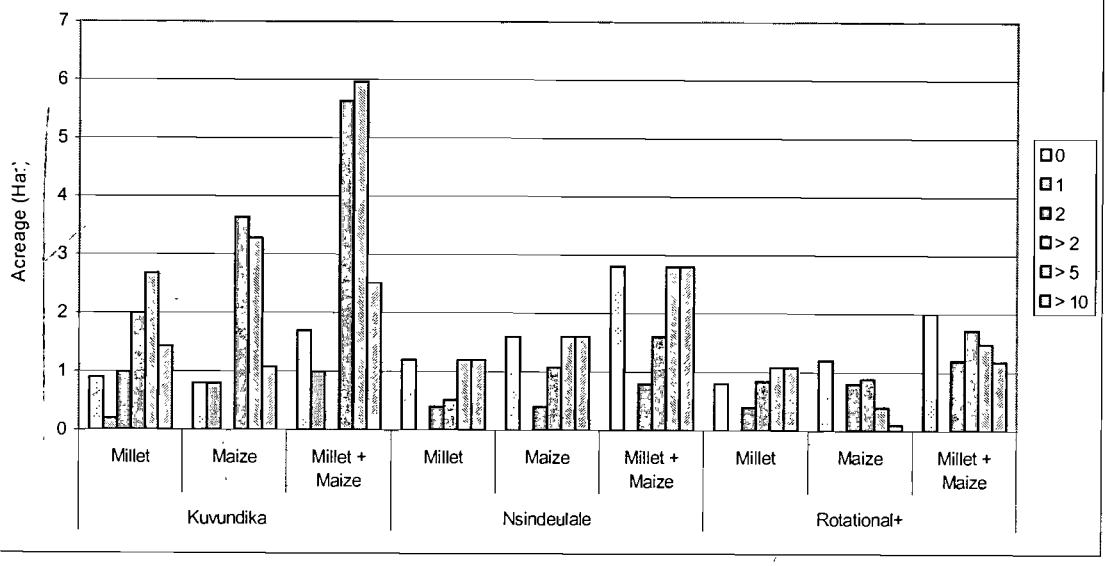
In addition to the use of oxen for cultivation, livestock is an additional source of cash and food to the family. Farmers can sell any livestock (chicken, goats, swine, cattle) for cash whenever need arises. Possession of livestock is linked to wealth, farmers with more herds of cattle are more wealthy, usually would also have ox-plough and ox-carts, and are more capable of cultivating finger millet and other crops. The farmers can have milk from their own cattle and may use the animals for food whenever need arises. Animal trampling of the field after sowing finger millet is an additional advantage.

Socio-economic and environmental parameters

Household system

A typical finger millet cultivating household is a married couple with several fields including finger millet field. In Mbozi District the majority of farmers had on average 8 acres of land per household with finger millet acreage about 2 acres. Few farmers reported having as much as 30 acres of land. Households were permanently settled; with mostly arable cropping except for farmers who cultivated coffee which is a permanent or perennial crop. Allocation of land for arable cropping gave priority to finger millet as an opening crop before virgin or long/short fallow land is cultivated with any other crop.

Fig. 4. Relationship between finger millet and maize acreages and number of cattle among ox-ploughing finger millet farmers in Mbozi District



Most finger millet farmers were monogamous but as much as 36.1% of those interviewed in Mbozi District were polygamous. Having more wives increased family size and workforce available for cultivation activities. The male parent was the household head and had overall control of all activities performed to sustain the household. Decision making in important household matters such as ensuring availability of food, clothing and shelter for the household all over the year is much more the responsibility of the male parent and it is him who is questionable when those needs are not met. Depending on system of production few activities such as cutting trees in slash and burn system, ploughing with oxen or crop haulage with ox-carts were performed by men only while things like making finger millet food or alcoholic brew are activities of women. Both male and female members, however know exactly their household needs and usually work in harmony towards achieving those needs. In most situations both male and female members of household participated if not equally, partially, in the finger millet production activities; and appropriated the products equally.

As already stated the level of production was partly determined by household parameters. Significant positive correlations were found to exist between household size and total acreage as well as finger millet and maize acreages. Amount of workforce available for cultivation was also related with acreages of those crops. Having more than one wife was positively correlated with increased agricultural activity; it led to increases in total acreage, millet acreage and, among ox-ploughers, maize acreage (Table) robably because of the opportunity for increased agricultural activity having more than one wife among farmers practicing ox-ploughing was significantly positively correlated with number of livestock the household possessed ($P \leq 0.01$). Number of livestock was also positively related with total acreage the household was in possession.

Socio-economic environment

Many socio-economic and environmental factors influence the level and characteristics of finger millet production in South Western Tanzania. Most important among them are cash economy of the people, the market in relation to remoteness or proximity to town, transport and communication, Government intervention etc.

Cash economy

Except in parts of Mbozi District where farmers produce coffee, most of the cash economy of the people in South Western Tanzania is mainly based on sale of excess of food crops. Among these crops finger millet is used almost exclusively for cash. Except in the coffee producing area of Mbozi District farmers in most of the research area obtain their cash mainly through sale of finger millet. The other food crops are minor sources of cash and are sold only occasionally when there is severe need for cash or when produced in excess of food needs, with precautions not to deplete food availability.

Market and transport

Because of the commercial nature of the crop presence of good and reliable market for the crop is very important. Both local and external market possibilities are almost always available. Farmers can sell the crop within the locality of the crop production but usually with much more difficulty and at lower prices. Local consumption rate is usually low, only enough to maintain the local alcoholic brews industry. External markets are those organized by middlemen or when the farmer carries the crop from the area of production to town centers where the market is more reliable. Transport logistics are however very poor for most of the production areas. Most of the production areas are inaccessible with public transport and can be reached with private transport arranged by middlemen only with a lot of difficulty. There are periods of the year especially during rains when some places are completely cut-off from any means of public transport. This influences very much farmer's planning and decision making on level of production. The poor local market and poor transport also make it very difficult for agricultural inputs to reach the production areas, thus seriously influencing characteristics of production activities.

Table 2. Associations of various finger millet production and household characteristics of farmers cultivating finger millet in Mbozi District.

	No. of wives	Household size	Work-force	Total acreage	Millet acreage	Maize acreage	Bean acreage	Groundnut acreage	Coffee acreage
Household size	0.64*** [a]								
	0.57* **								
Workforce	0.56***	0.84*							
	0.54* **	**0.85*** **							
Total acreage	0.24*	0.25*							
	0.38*	**0.39***	**0.43***						
Millet acreage	0.27*	0.41***	0.32**	0.36***					
	0.3	**0.56*** **	**0.39*** **	**0.69*** **					
Maize acreage	0.22	0.52***	0.39***	0.13	0.7***				
	0.5*	**0.76*** **	**0.49***	**0.09**	**0.75*** **				
Bean acreage	-0.12	-0.002	0.08	0.19	0.61	-			
	0.03	**0.2**	**0.16**	**0.73*** **	**0.76*** **	**0.13**			
Groundnut acreage	0.31	0.25	0.05	0.5**	0.07	0.1	0.22		
	0.001	**0.0001**	**-0.77**	**-0.59**	**-0.64**	**-0.77**	**0.13**		
Coffee acreage	-0.1	0.13	0.19	0.35	-0.1	-0.37	-0.18	0.35	
	-0.34	**0.07**	**0.13**	**0.05**	**-0.31**	**-0.87****	**-0.48**	**0.53**	
No of cattle	0.21	0.25	0.15	0.13	-0.11	0.11	-0.46	-0.38	-
	0.53**	**0.35**	**0.5****	**0.53****	**0.04**	**-0.04**	**-0.04**	**-0.95*** **	**0.24**

* Significant at 0.05 level ** Significant at 0.01 level [a] All farmers
*** Significant at 0.001 level n is variable Bold Ox-ploughers

Policy

Government policy and intervention also influence production characteristics of farmers. For example the Government land use and forestry policies restrict the use of woodland areas for agricultural activities or prevents use of fire for clearing farm fields thus influencing specific agricultural practices such as slash and burn cultivation. Crop development, promotion and support policies and actions can also influence production characteristics. During this research it was found, for example that the level of application of slash and burn cultivation is very low largely because of Government legislation on environmental conservation and forestry.

Others

There are many other socio-economic factors that have influence on finger millet production. Local culture and tradition of making and drinking local alcoholic brews, for example, were found to be very important incentives for finger millet cultivation. Indigenous knowledge systems and lack or limitation of diffusion of modern agricultural practice are also very much determinant of the farming systems characteristics of the research area.

Physical environment

Physical environmental features such as woodland environments, grasslands and drainage characteristics in the *mbuga*, for example, determine the extent and efficiency of production. It is also important to note that the finger millet farming systems described in this research are rain-fed. Farmers plan their agricultural activities with focus on known rainfall characteristics of the environment.

Conclusion

Via component analysis the cultivation systems, cropping cycles and cropping patterns as well as the interaction of the aforesaid with other land use activities such as livestock keeping and the human resource, physical and socio-economic environments can be explained in detail. During this research important characteristics of the farming systems in which finger millet is cultivated in South Western Tanzania have been explained. It has been evident that the crop is produced under typically traditional systems that

strive to make best use of natural productive resources. There is need to study more the scientific as well as socio-economic and environmental parameters that are responsible for sustainance of the systems, and constraints that must be checked to improve the systems performance.

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