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Farming systems dynamics: Impact of increasing population density and the availability of land resources on changes in agricultural systems. The case of Sukumaland, Tanzania

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Abstract

The changes in agricultural production systems over the period 1875 till 1990 have been analysed for three districts belonging to Sukumaland, Tanzania. The analysis is based on historic information for the early period, on data from agricultural studies conducted in 1945 and 1961, and on recent field studies in 1990–1992.

Increasing population densities and therefore decreasing availability of agricultural land per capita has occurred generally. In addition, there exist important agro-ecological differences between the three districts that have also been responsible for the present diversity in farming systems. Among these, differences in rainfall and the relative availability, quality and type of land resources, as related to toposequential land units, are of major significance. Together these factors determined the potential and subsequently the changes that have occurred during the past 50 years in the major land use systems and crops for the various parts of Sukumaland.

In anticipating the direction of agricultural developments and consequently the sustainability of actual and future agricultural systems, differences in the principle agro-ecological factors of soils in relation to the topography (landscape units) should be considered more closely. Such information should be used to complement the broad socio-economic considerations on which most policy decisions, including development aid, are currently based.

Keywords: Farming systems; Sustainability; Tanzania; Rural development

1. Introduction

At the 1992 UNCED meeting in Rio de Janeiro it was frequently emphasized that increasing population density will lead to land degradation and eventually to increased poverty of the population. There are indeed many studies which illustrate the various threats to African agriculture in terms of erosion, soil mining, soil acidification, as well as deforestation and overgrazing (Stoorvogel and Smaling, 1990; Carter et al., 1992).

In contrast to the above 'Malthusian' thoughts, Boserup (1965) argued that population growth is a precondition for development since it eventually forces the population to intensify land use. As a result, the growth rate of food production will also accelerate (Boserup, 1981). This view is supported by a recent field study in the Machakos District of Kenya by Tiffen

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and Mortimore (1992). In this area population density had reached 135 inhabitants per km^2 in 1990; yet the value of output per caput and per hectare increased by factors of approximately three and ten respectively over the period 1930–1990, whereas erosion decreased considerably. It is unclear, however, to what extent these favourable developments are a function of the prevailing agro-ecological conditions which elsewhere in Africa are often more marginal. Furthermore, the relationship between population growth and agricultural expansion is unlikely to be a linear one. It is still poorly understood to what extent phases of land use intensification are followed by extensification and vice versa.

In order to reconcile the opposing viewpoints about the impact of population growth on agricultural developments it is necessary to consider the population density and the availability of land per capita for specific regions in relation to the agro-ecological potentials (soil resources and climate) of these respective regions.

Sukumaland offered an excellent opportunity for this type of comparison. Detailed data are available from earlier studies in 1945 and 1962 and can be compared with data from 1990–1992. The area is characterized by considerable variations in agro-ecological potentials: the climate is semi-arid with unpredictable rainfall patterns (annual averages range from 1000 mm in the Mwanza district near Lake Victoria to 700 mm or less in the Meatu district); soil potentials vary greatly in response to their positions along the catena. Compared to those in the Machakos District of Kenya, farming systems in Sukumaland are rather 'closed': the use of external inputs like fertilizer is minimal for reasons of poor infrastructure and lack of readily accessible markets. In spite of these conditions the population density increased greatly throughout the area over the period 1945–1990: from 50–115, and from 15–30 inhabitants per km^2 for the Mwanza and Meatu areas respectively.

In some respects this study is similar to the Machakos work. However, in contrast to the studies by Tiffen and Mortimore (1992), agro-ecological differences, in particular in soils and rainfall, are emphasized as primary factors that have critically affected the agricultural development and production processes, besides population growth.

2. Materials and methods

Sukumaland mainly covers the area between the Speke Gulf of Lake Victoria and Lake Eyasi. It consists of ten districts: Ukerewe, Mwanza, Magu, Sengerema, Geita, Kwimba, Bariadi, Maswa, Meatu and Shinyanga (Fig. 1). The Sukumaland study by Meertens et al., 1995 is based on results obtained from agricultural surveys (ICRA, 1990; Bantje, 1991; Meertens and Ndege, 1993) conducted around 1990. Subsequently these results are compared with similar data from 1945 and 1962, as reported in the literature (Rounce, 1949; Collinson, 1963; Collinson, 1964; Collinson, 1972); in addition, historical reports (Stanley, 1899) about the area are reviewed. The data sets for 1945, 1962 and 1990 are interpreted against the agro-ecological conditions of Sukumaland in terms of its climate, soil catena and predominant vegetation, wildlife/ livestock and pests. The major political events and the associated changes in agricultural policies that have occurred from 1875 to 1992 were also taken into account.

3. The setting

3.1. History

The major historic events that most profoundly affected the Sukumaland agriculture have been summarized in Table 1. People started to settle in Sukumaland in the 16th century. In 1875 Henry Morton Stanley travelled through Sukumaland and described it as a land of plenty (Stanley, 1899). At that time Sukumaland was composed of several chiefdoms with frequent wars among them. Most probably these wars were sparked by the profitable trade of war prisoners as slaves. In 1890 Tanganyika became a German colony and the imposed military rule practically ended the warfare among the chiefdoms. Tanganyika became a British protectorate after the First World War. It was only after the Second World War, with the increased demands for raw materials from Europe, that an ambitious agricultural development scheme was started for Sukumaland (1947–1956).

After independence (1961), the Arusha Declaration of 1967 set in motion a socialist strategy aimed at nationalization and the creation of Ujamaa villages. By 1985 the Tanzanian government made an agreement

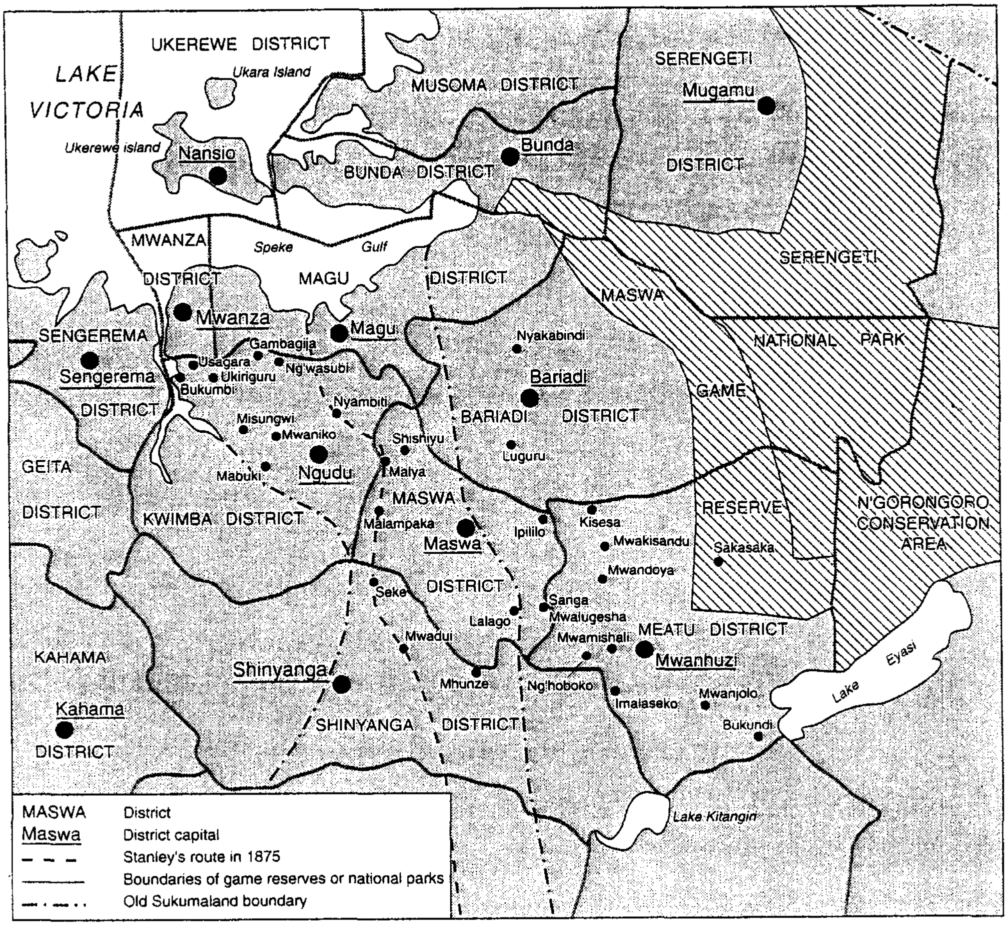


Fig. 1. Map of Sukumaland. Source: Meertens et al., 1995.

Table 1
Main events in Sukuma agricultural history

	Factor	Description of event	Implications
±1500	Population density	Scarcity of wild animals near Tabora due to population growth	Migration of people to grasslands in the north
±1800	Policy	Warfare between chiefdoms	Intensive agriculture on fields near houses
1890–1919	Policy	German colonial period	Pacification and extensification of agriculture
1920–1960	Population density	Build-up of people and livestock in Mwanza and Kwimba	Migration of cattle-owning households to Maswa and Shinyanga
1930–1967	Economy	Increased cotton production; good prices and marketing channels	Increased wealth; more livestock units per household
1947–1956	Policy/Ecology	Tsetse eradication by British colonial administration	Migration of households to Meatu and Geita
	Technology	Availability of ploughs	Extensification of agriculture
1967–1986	Policy/Economy	Declaration of socialist Ujamaa philosophy	Decline in cotton production and economy in general
1986–1989	Policy/Economy	Economic recovery programme (IMF)	Gradual abandonment of Ujamaa; signs of economic growth
1990	Population density	Increased rural population density	Intensification of agriculture

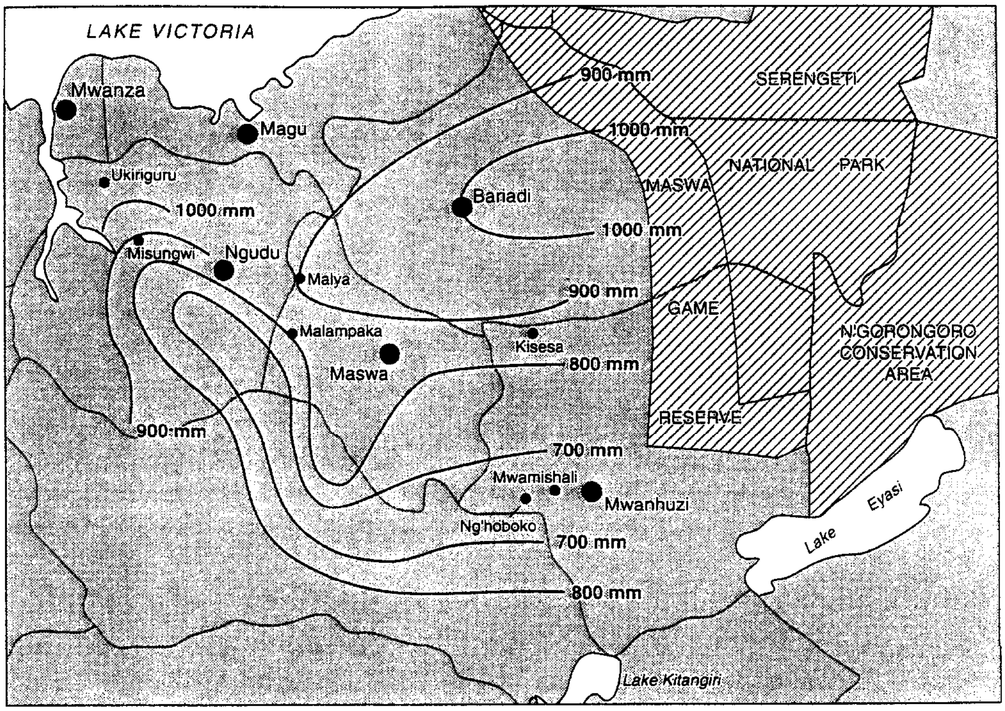


Fig. 2. Rainfall in Sukumaland. Source: Meertens et al., 1995.

with the IMF to liberalize the economy, which also led to abandoning gradually the Ujamaa philosophy.

3.2. *Agro-ecology of Sukumaland*

The area has a moderately warm climate with daily temperatures varying between 15° and 30°C throughout the year and a mean annual daily temperature of about 23°C. Average annual rainfall ranges between 700 mm and 900 mm with higher rates (1000-1100 mm) near Lake Victoria and lower ones (400–500 mm) near Lake Eyasi. Fig. 2 shows that the rainfall decreases gradually from Lake Victoria to Lake Eyasi and from Serengeti National Park to Maswa District.

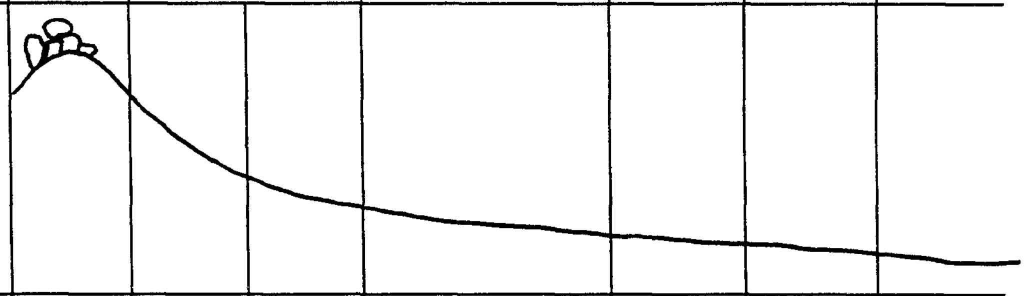
Generally, the rains start by mid-October and end by mid-May. The pattern is bimodal with peaks in November–December and March–April; prolonged dry spells are common in January and February. The dry season is from June–October. Apart from this general pattern the rainshowers are very localized and unpredictable.

The altitude of the area varies from 1000–1300 m above sea-level. The landscape is characterized by broad and narrow valleys separated by rocky hills that consist mainly of granitic and sometimes gneissic rocks. There are also some vast alluvial (fluvial and lacustrine) plains derived from the same types of rocks.

Typical soil catenas, first described by Milne (1947), have developed in the granite parent material (Fig. 3). The local Wasukuma population has a thorough knowledge of the catenas and recognizes the predominant soil types by specific names. Moreover, the different cropping systems and local production technologies are closely adapted to soil characteristics as discussed in a recent paper by Ngailo et al. (1993). The distribution and relative importance of the different soil types along the catena are greatly influenced by the steepness and length of the slope. For the area around Ukiriguru (Fig. 1) the dominant soil type in the catena is Luseni, which is an acid, bleached sandy soil with poor structure and very low natural fertility. Closer to Mwanza the hills are much steeper; here the dominant soil type is Isanga, which is a coarse, sandy to gravelly sandy loam. Clayey soils are almost absent in this catena.

Elsewhere in Sukumaland (Kwimba, Bariadi and Maswa Districts) most valleys are broad and gently

landscape feature	granite hill with tors	upper footslope		lower footslope	valley margin	valley floor	seasonal swamp
type of soil and characteristics	dark grey loam, skeletal	brownish red loam direct on granite	brownish red loam murram in sub-soil	grey sand, irregular murram in subsoil	hard-pan soil, not calcareous	black sandy clay, calcareous	heavy black clay
local name	*luguru*	*ikurusi*	*isanga*	*luseni*	*ibambasi*	*itogolo*	*mbuga*



Source: based on Milne (1947).

Fig. 3. Soil catena of Ukiriguru.

undulating to almost flat so that the catenas are longer than the one in Fig. 3. The dominant soil types are then Ibambasi and Itogolo which are alkaline sandy clay hardpan soils.

Besides the catenas there are vast, almost flat, plains which developed on old alluvium. These plains are common in Maswa, Meatu and Shinyanga Districts; the dominant soil types are Ibambasi and Itogolo or Mbuga, a dark cracking clay, or Ibushi, a calcareous friable, clay loam. The respective locations of the catenas and valleys in Sukumaland are indicated in Fig. 4.

The natural vegetation of the area dominated by the Ibambasi and the Itogolo hardpan soils consists mainly of perennial grasses and some scattered shrubs (*Acacia fischeri*, *Acacia mellifera*, *Commiphora campestris*, *Lannea humilis*). To the west and east of these grasslands the area was covered by thorn bushlands with shrubs like *Acacia drepanolobium*, *Acacia spirocarpa* and *Acacia mellifera*.

4. Changes in Sukumaland agriculture

Throughout history there have been frequent changes in farming practices and consequently in the intensity of farming. For European agriculture these changes have been described in detail by Slicher van Bath (1977) for the period 500–1850. Such studies serve to identify the crucial factors that have triggered agricultural developments, as well as their impact on

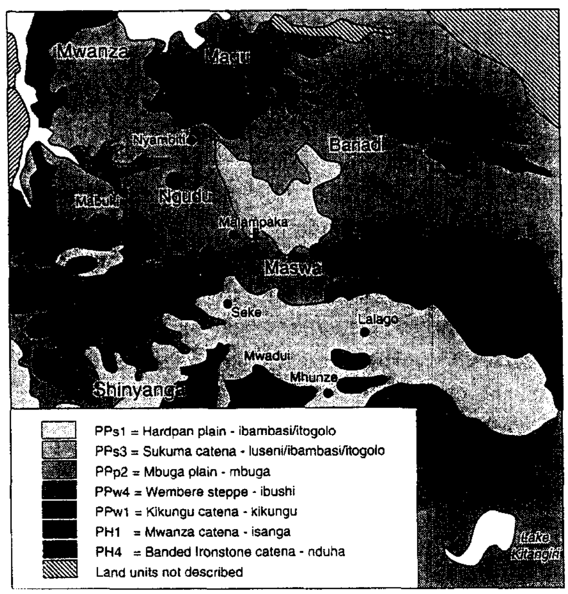


Fig. 4. Physiography and soils in Sukumaland. Source: Meertens et al., 1995.

Table 2
Population density changes in different parts of Sukumaland since 1945

	Old Mwanza District	Old Kwimba District		Old Maswa District	
1945[a]	51	51		25	
1957[b]	51	52		30	
	Usagara Division	Kwimba District	Sengerema Division	Maswa District	Meatu District
1967[c]	-	-	45	39	14
1978[c]	94	58	58	49	22
1988[c]	114	70	72	62	27

Sources: [a]Rounce (1949); [b]McLoughlin (1967); [c]Tanzanian Government census data

Table 3
Changes in average household size, arable land per capita and total cropped area per household over the period 1945 to 1991 for three regions in Sukumaland

	Old Mwanza		Old Kwinmba			Old Maswa		
	1945	1990	1945	1962	1991	1945	1963	1991
Average household size	6.8	6.6	7.1	8.2	6.7	8.1	10.1	6.8
Arable land per capita (ha)	0.39	0.27	0.44	0.32	0.31	0.30	0.31	0.37
Number of livestock per capita	1.3	1.0	2.2	1.4	1.1	3.3	3.1	1.2
Total cropped area per household (ha)	2.63	1.77	3.10	2.59	2.05	2.40	3.10	2.49

agricultural production and its sustainability for specific regions. Although the historic data base for African agriculture is much less detailed than for Europe, there are remarkable similarities in the types of developments and their causes.

Land use intensification, i.e. the increased use of land over space and over time, is an intricate process that may take several forms (Carter et al., 1992). Agricultural intensification implies an increase in total input use per unit land area (in particular for labour). Agricultural extensification implies an increase in total area cultivated (or used) and tends to be the initial response to a growing rural population.

Obviously, a most important factor in agricultural developments in Sukumaland during this last century has been the large population growth. Differences in population density are associated with a differential land use intensification pattern, as shown by the farm management data from 1945, 1962 and 1990 for three subregions, within the boundaries of Old Mwanza, Old Kwimba and Old Maswa Districts. The prefix 'old' is used because administrative boundaries have changed over the years. In 1945 and 1957 Mwanza District included Usagara Division and parts of Magu and Geita Districts; Maswa District included the areas that are nowadays Bariadi and Meatu Districts (Fig. 1).

4.1. Population density

Population density has always been higher in the Mwanza and Kwimba Districts than in the Eastern Districts of Maswa and Meatu (see Fig. 1 and Table 2). After the Sukumaland Development Scheme (1947–1956) an overall increase in population and livestock density took place in almost every part of Sukumaland because the nearby possibilities for migration were limited to the Maswa Game Reserve only.

Table 2 presents the changes in population density for various parts of Sukumaland since 1945. The population in Usagara Division has increased to 114 persons per km^2 in 1988 so that all land is currently occupied and almost no fallow exists anymore. The average cultivated area per household decreased to 1.77 ha and the per capita availability of arable land to 0.27 ha in 1990 (Table 3). Households therefore had to obtain their food and cash from smaller and fewer fields; the resulting agricultural intensification led to a land-use intensity factor (R)[1] between 80 and 100.

[1] R = (number of crop cycles per year × number of years of cultivation × 100):(number of years of cultivation + number of years of fallow) (Ruthenberg, 1980).

Much lower population densities of 62 and even 27 persons per km^2 occur presently in Maswa and Meatu Districts respectively. For these Districts there is still no shortage of land. The average cultivated area per household was 2.5 ha in 1990 in Maswa, the average household size being the same as for Mwanza. For Meatu the cultivated area amounts even to 4.1 ha per household. These parts of Sukumaland have R-values between 40 and 75.

4.2. Land use patterns

The initial settlers may have moved to Sukumaland several centuries ago because of the abundant game living in the grass plains. These grasslands were located on hardpan soils where consequently very few trees could grow. Moreover, because of the limited shade the tsetse flies also were absent. The grasslands were bordered by tsetse- infested thorn bushlands. Thus, as arable farming gradually replaced hunting, the first settlements were concentrated in Kwimba and parts of Bariadi, Maswa and Shinyanga Districts (Fig. 1 and Fig. 4) and comprised a mixed livestock-arable farming. The cropping component of the system occupied the sandy soils on the upper slopes near the rock outcrops which are easy to cultivate with handtools.

Because of the local threats of warfare the village lands for grazing and planting were limited to the immediate vicinity of the houses. The resulting land shortages led to intensified cultivation practices (including manuring) and a system of land tenure. However, in 1890, when the Germans 'pacified' Sukumaland it soon became safe to settle further away from the villages. Subsequently, this led to farm expansion and extensification of the farming practices (Tomecko and Tomecko, 1976).

During pre-colonial times the land occupation pattern was strongly affected by an equilibrium between, on the one hand, grassland and agricultural areas (free of tsetse) where people and cattle lived, and tsetse-infested woodlands with game on the other hand. With the occurrence of the rinderpest pandemic in 1891, which attacked both cattle and game, and the simultaneous outbreak of human disease epidemics (smallpox and jigger flea), the importance of grasslands decreased. Grassland was partly replaced by woodland which was tsetse-free due to the absence of game and cattle. Subsequent human population growth led to a recolonization of the woodlands. Around 1920 the people again met with the tsetse which resulted in a serious outbreak of trypanosomiasis (Birley, 1982). In the 1920s, one of the first activities by the British colonial government in Sukumaland was an effort to eradicate tsetse by removing shrubs and trees. This programme started in Shinyanga and continued in Maswa between 1931 and 1935.

A next phase in the agricultural extensification process started with the introduction of ox cultivation in 1934. Only after 1945, with the start of the Sukumaland Development Scheme (1947–1956) and the expansion of cotton production (Fuggles-Couchman, 1964), did the ox ploughing lead to large increases in farm sizes (from an average of 2.5 ha to 4.0 and even 5.0 ha in Meatu). Under this Scheme 30 000 people moved in 5 years to the Geita District. Moreover, the clearing of tsetse-infested bush in Meatu District provided additional areas for cattle grazing (Fuggles-Couchman, 1964).

Since 1875 the farming systems in Sukumaland have passed through a series of land-use extensification phases. It started with the end of the local warfares under German colonial rule when people could freely expand their farms. Next, the introduction of ploughs allowed the cultivation of the clayey soils on the lower slopes and in the plains which earlier, when only handtools were available, had been too difficult to cultivate. Subsequently, the eradication of tsetse has opened huge new areas for livestock and arable farming using animal traction. Together, these factors have led to large farms on the predominantly clayey soils of the Meatu District in particular. Since these clayey soils occur on the lower slopes and in the plains ploughing did not lead to increased erosion, as has been the case in the more sandy soils of sloping areas in, for instance, the cottonbelt of South Mali.

4.3. Cropping patterns

There are distinct differences between the cropping patterns of the major Districts of Sukumaland and the ways these have changed over the last 50 years. Crucial factors have been, on the one hand, the population density and the availability of certain preferred land types, and, on the other hand, the presence of reliable and remunerative markets for farm products and the introduction of new technologies (mainly animal traction and farm implements).

The two staple crops in Sukumaland around 1945 were sorghum (*Sorghum bicolor*) and bulrush millet (*Pennisetum typhoides*). These two cereals are more tolerant to droughts than maize. In addition, sorghum can withstand temporary waterlogging whereas millet will give economic yields even on exhausted, infertile and drought-prone sandy soils like Luseni and Isanga. Only cassava will outyield millet on these soils. Rice cultivation on the clayey hardpan soils of the lowlands was limited because of the high labour inputs that were required for field preparation.

Throughout Sukumaland the main cash crop around 1945 was cotton. Its production was further enhanced by the extension of the railway line from Tabora to Mwanza in 1928. This drought-tolerant crop was most important near the Lake and during 1935–1944 one half of the total Sukumaland cotton production came from Old Mwanza.

Table 3 shows that by 1990 the cropped area per household and arable land per capita had declined substantially in Old Mwanza and Old Kwimba due to the increased population density. For Old Maswa where the overall population density is lower these trends are opposite. During the same period also the relative importance of different crops has drastically changed from the 1945 situation (Fig. 5). Most remarkable is the decline in dryland cereals (in particular bulrush millet and sorghum) and the increased importance of rice in all three of the districts. Moreover, the expansion in cotton production during the 1960s has been followed by a steep decline in the 1970s and 1980s. Bulrush millet, important in 1945, is hardly cultivated in 1990; sorghum became one of the many crops intercropped with maize, which became the predominant dryland cereal crop. Thus by 1990 maize and rice had become the two major cereal crops.

Apart from these overall trends there have also been important, local changes (see Table 3 and Fig. 5). In Usagara Division (Old Mwanza) a considerable decrease in available land per household and per capita has resulted in intensification of crop production. Intensification leading to an increased production per unit area has resulted mostly from higher labour inputs (weeding, preparing and applying manure) and to a much lesser extent from capital inputs such as mineral fertilizers. In this process sorghum was replaced by selected maize and rice varieties, since the latter crops are more responsive to intensive cultivation. Maize yields increased in Usagara from 800 kg ha^{-1} around 1945 to 1500 kg ha^{-1} in 1990, while rice yields increased from 1700 kg ha^{-1} to 3375 kg ha^{-1} over the same period (see Table 4). Likewise cassava has completely replaced bulrush millet on the exhausted Luseni soils because of its higher yield potential under these conditions. Moreover, by 1990 intensive cultivation of horticultural crops, in particular tomatoes, for the nearby Mwanza market had replaced cotton as a cash crop; simultaneously the significance of off-farm employment increased as well.

In Old Kwimba the agro-ecological conditions are somewhat different. Consequently, sorghum was the most important crop in 1945 and was widely grown on the clayey and wet Mbuga soils. Bulrush millet, the second major crop, was grown on the sandy soils where the cassava acreage was not yet important. During the 1960s high profits and a good market organization through local cooperatives stimulated an increase in cotton cultivation (up to 40% of the cropped area per farm) at the expense of the traditional food crops. To compensate for this loss in food grains cassava replaced millet on the sandy soils and intensive rice cultivation was introduced in the valleys. Moreover, the wealth and security from cotton allowed the increased cultivation of the risky, but preferred, staple food maize.

In contrast, the Sengerema Division of Old Kwimba is mainly located on a huge, almost flat plain dominated by hardpan soils. There are only a few sandy soils. Consequently, cassava is not important and sorghum is grown mainly as a food security crop. Following the increase in population density (Table 2) and the introduction of ox ploughs, the farmers expanded their rice areas on the hardpan clay soils at the expense of sorghum and maize. Initially, cotton competed with rice, but since the 1970s rice has been more profitable and by 1991 it had become the main food and cash crop for Sengerema Division.

The developments are again different for Old Maswa District, being a new settlement area from around 1945. At that time population density was only half that of Old Mwanza and Old Kwimba (Table 2). Because the grasslands in Mwanza and Kwimba could no longer support the increased number of animals, the cattle owners migrated to new grasslands that were recently freed from tsetse. Clayey soil types are dominant in Old

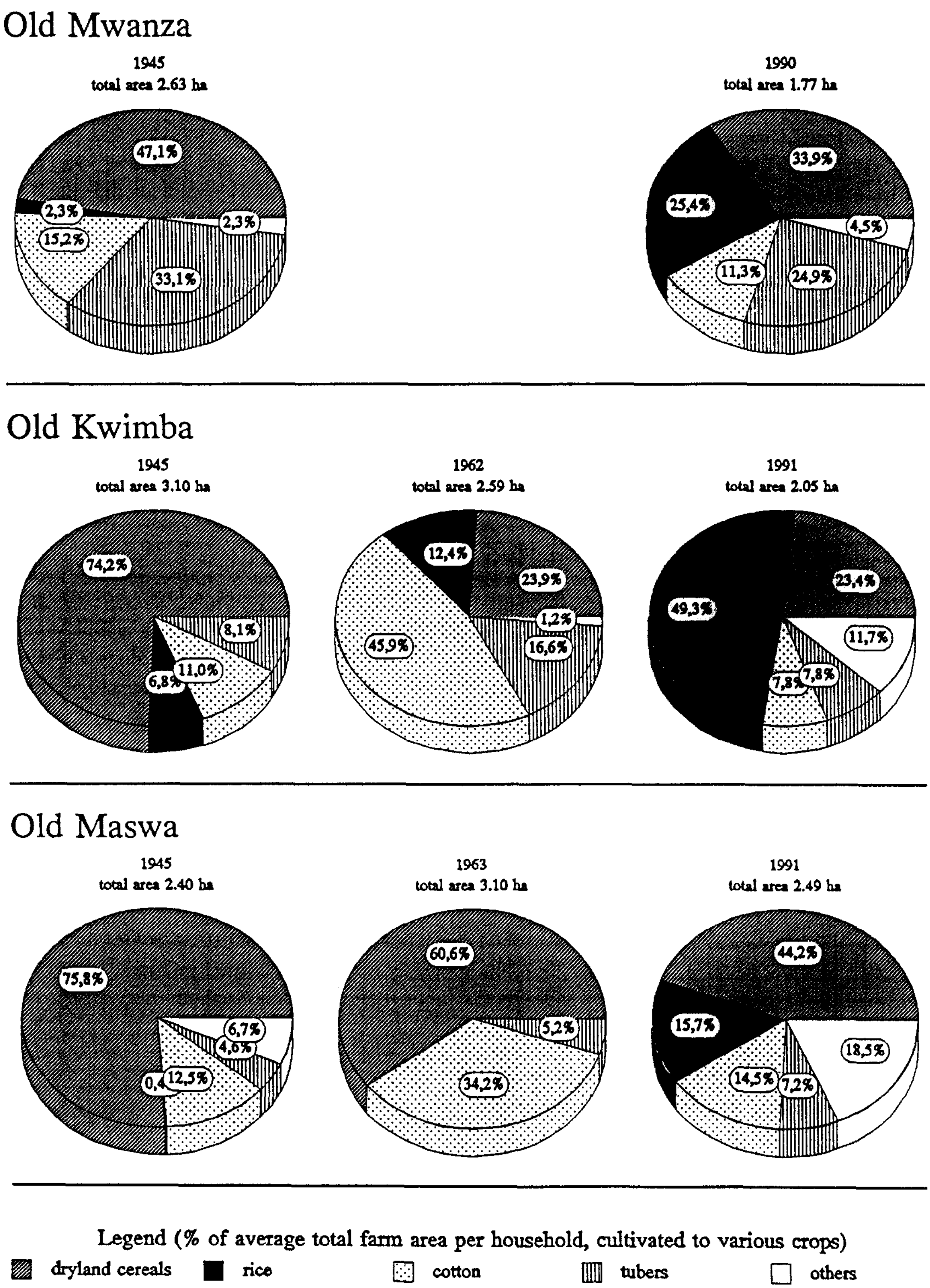


Fig. 5. Changes in the relative importance of the major crops grown by farm households in three districts of Sukumaland over the period 1945–1990. Dryland cereals include bulrush millet, sorghum and maize

Maswa and in 1945 the most important cereal was therefore sorghum and the main cash crop cotton. The relatively small total crop area at that time (Table 3) reflected the preoccupation of the households with livestock, as well as the fertility of the virgin land. Fig. 5 also shows that the cotton areas had increased more than threefold by 1963 because of the abundance of land and the introduction of oxploughs. The other major change was the partial replacement of sorghum by maize and rice as the preferred staple crops. The security and wealth generated by the cotton production stimulated farmers to grow maize instead of sorghum in spite of the drought risks. Yet, in the absence of cassava and bulrush millet, sorghum remained important as a security crop while the further expansion of rice is limited by the lack of suitable hardpan soils and the lower average annual rainfall (Fig. 2).

4.4. Livestock ownership

In Tanzania the word Sukuma is strongly associated with the ownership of many heads of cattle, the predominant race being the Tanzanian Shorthorn Zebu. The livestock population has indeed been increasing enormously following the rinderpest epidemic of 1891. By 1991 about half of the households owned livestock in almost every part of Sukumaland. However, the number of livestock units per household had decreased everywhere because of the increase in the total number of households (Table 3).

In Old Mwanza less than 50% of the households owned livestock during the period of 1945–1962; for Old Kwimba this was 60%. This reflects the shortage of grasslands (only 0.5 ha per capita) and steep slopes of the area. The highest percentage of livestock ownership (70–90%) is recorded for Old Maswa as a result of the migration of livestock owners following the eradication of tsetse in the 1950s. However, with increasing population density and the resulting increased importance of arable cropping, livestock holding had decreased in Old Maswa from three to only one animal per capita by 1991.

4.5. Intensification of land use

The application of inputs like manure and mineral fertilizers has been very low in Sukumaland, as is typical for many of the relatively 'closed' farming systems in Africa. For decades, the large supply of virgin lands virtually eliminated the need to improve soil fertility through manure or mineral fertilizer applications. Consequently only 3–5% of the households used manure or fertilizers during the period 1945–1990. FAO estimates that in the period 1985–1994 an average of only 2 kg ha^{-1} $year^{-1}$ mineral fertilizer was used in the Mwanza Region, and even less in the other regions.

Low input use is currently coming to an end for the area near Mwanza town. The drastic reduction in available land per household forces people to intensify their production system so that higher yields are realized on smaller areas. Manure and fertilizer usage is slowly increasing and even the households without cattle are starting to buy manure. The total availability of animal manure is being estimated at 1000 kg ha^{-1} $year^{-1}$ as based on a calculation of the total quantity produced in the kraals and the total cultivated area of Mwanza Region. For the area near Mwanza occasional applications of 2500 kg ha^{-1} manure are made mostly to the horticultural fields on the sandy soils.

This development is mirrored in the yield trends for the different areas. While the rice and maize grain yields per hectare have doubled in Old Mwanza since 1945 (see Table 4) this trend does not occur in the other parts of Sukumaland where land is still relatively abundant.

5. Discussion and conclusions

Around 1945, Rounce (1949) estimated that 39 people per km^2 would be the optimum population density given the ecological conditions in Sukumaland. On this basis the 'overpopulated' areas were resettled at carefully controlled densities and new areas were opened up. Better farming methods like (green) manuring,

Table 4
Changes in maize and rice yields

	Usagara Division		Sukumaland	
	maize (kg ha^{-1})	rice (kg ha^{-1})	maize (kg ha^{-1})	rice (kg ha^{-1})
1945[a]	800	1700	800	1700
1990[b]	1500	3375	785	1600

Sources: [a]Rounce (1949); [b]ICRA (1990); Meertens et al. (1995)

mulching, erosion control, (tie-)ridging, pasture improvement, use of fodders and mechanization had to be adopted throughout Sukumaland to secure a sustainable agriculture.

By 1988, however, population densities, with the exception of Meatu, had become two to three times as high as the optimum calculated by Rounce (1949) (see Table 2). Moreover, almost all of the improved farming methods advocated by Rounce (1949) had been rejected by the farmers. Yet, even though the farming systems have remained relatively 'closed' with very limited use of external inputs, the predicted environmental disasters and famine have not occurred. It may be concluded that food production has kept pace with population growth, in spite of, or possibly because of, the considerable expansion of cotton; the latter holds if revenue from the cotton was used to purchase food.

The initial response by the Wasukuma population during the period 1945–1990 has been to expand their farms and to shorten the fallow periods. Subsequently, however, a wide range of other important, local changes, not foreseen by Rounce (1949), were introduced. These included:

1. the replacement of bulrush millet by cassava, which is a higher yielding crop on the sandy Luseni soils;
2. the partial replacement of sorghum first by cotton and subsequently by selected maize and rice cultivars on the Itogolo and Mbuga soils; the latter two cereals are higher yielding than sorghum;
3. the cultivation of rice on the lower slopes and lowland clay soils that previously were too difficult to manage with handtools;
4. the development of a local water harvesting technique which has facilitated the expansion of rice cultivation (FSR Project Lake Zone, 1989; Meertens and Ndege, 1993).

The changes in land use intensity in Sukumaland thus have been accompanied by changes in land types utilized, in crop choice, and in crop and animal husbandry techniques, including lately the use of more external inputs on those fields that are most intensively cultivated (i.e. in the Old Mwanza District).

Differences in agricultural production systems for various parts of Sukumaland may be explained to a large extent by the ecological factors such as soils, rainfall regime and the tsetse vegetation interaction in combination with differences in population densities. A crucial stage in land use intensification arrives when the land frontier is reached and no more fallow land is available. Only substantially increased labour inputs per unit land (e.g. for weeding and for manure production and application) will then allow the maintenance of farm level food production and cash income. However, this stage is generally accompanied by a sharp decline in labour productivity because the local crop cultivars respond poorly to additional inputs. Therefore the initial response of farmers in Sukumaland and elsewhere has been to migrate to less populated areas. Only when these options were exhausted did labour inputs increase considerably. A comparable situation has been described by Slicher van Bath (1977) for agricultural development in Western Europe. Similar patterns seem to hold for other parts of Africa: the cotton belt of Southern Mali (Stoop, 1993), and the Machakos area in Kenya (Tiffen and Mortimore, 1992).

In addition, however, these studies indicate that with respect to sustainable production systems population densities in the range of approximately 30–60 inhabitants per km^2 are critical because it is at this level that fallow lands become increasingly scarce (Boserup, 1981). Obviously, this population threshold level will depend also on the agro-ecological conditions; for drier areas and for more marginal soils it will be reached at lower values.

At these threshold population levels the common smallholder farming systems in the vast, non-industrialized areas of Africa become 'squeezed'; the fields are increasingly being cropped permanently, yet neither the infrastructure, nor the local demand for farm products is sufficient to generate an economically justified intensification through the increased use of external inputs (Stoop, 1991). Negative nutrient balances and progressive soil mining indicative of production systems that will be non-sustainable in the medium to long term therefore appear an unavoidable consequence. Such situations have also been reported extensively by van der Pol (1992) and Smaling (1993).

Both the Machakos and the present Sukumaland studies indicate that, provided the land degradation does not take on irreversible forms like serious gully erosion, an area can well be regenerated through intensification. In both studies rural population densities had to reach levels of about 100 inhabitants per km^2 (at first only in the immediate vicinity of urban centres) before intensification based on external commercial inputs became economically feasible.

Obviously, population growth per se has not been the only determining factor. For Sukumaland changes in the economic conditions and in government policies have caused an explosion in cotton growing during the 1950s and 1960s. As a result land use intensity increased drastically, leading to further change. Yet, the start of the Ujamaa policy in 1967 coincided with the beginning of a long period of decline in cotton marketing and production as well as a general collapse of the Tanzanian national economy. As a result rice has presently replaced cotton as the principal cash crop.

As the development of cotton production in Sukumaland demonstrates, the economic factors such as good prices and reliable marketing channels have greatly affected the change pattern. However, as has been the case also in the cotton growing areas of West Africa, most capital accumulated through cotton sales was subsequently invested in larger livestock herds rather than in intensified agricultural practices through increased use of external inputs like farm implements and agricultural chemicals. In theory these inputs might have led to considerable increases in crop yields and labour productivity. However, it is significant for the socio-economic conditions in the rural environment at that time that this did not happen. Instead the areas had first to pass through another cycle of environmental degradation, due to increasing livestock herds, before intensified animal husbandry practices (e.g. stabling and controlled grazing) became unavoidable and economically more profitable than the traditional practices (Bosma et al., 1993).

This pattern of gradually increasing the land-use intensity, partly through agricultural extensification, with growing population density fits the Boserup thesis (Boserup, 1981). However, whether further land-use intensification, as in the Usagara Division of Sukumaland, will eventually lead to more wealth or poverty is yet uncertain. It is also possible that the situation will evolve towards one of agricultural involution, as documented by Lagemann (1977) for Eastern Nigeria. Whatever will be the case, this study demonstrates again that economic and political factors, over which individual farmers have little control, are also crucial. These contextual factors include national policies favouring rural investments and the availability of suitable technologies and relative factor prices. Together these determine the local conditions that decide whether ecologically sustainable intensification is possible and whether population growth will lead to wealth or to land degradation and poverty (see also Ruthenberg, 1980; Pingali et al., 1987; Lele and Stone, 1989).

The present study draws attention to the complex inter-relationships between the dynamics of agricultural production systems, the varying degrees of sustainability associated with different systems and the socio-economic context. Thus the means, and therefore the types of technologies, that will be available to small farmers in addressing the sustainability problems will necessarily differ greatly between regions with different population densities (see also Enserink et al., 1994).

The experiences of Rounce in Sukumaland, as well as those from many development projects elsewhere, demonstrate that technologies aimed at improving sustainability are readily rejected by farmers when not sufficiently relevant to the prevailing socioeconomic conditions. This implies that farmers will adopt different types of technologies depending on the level of development and intensification of their farming system. For instance, only when all available fallow land is fully used do the incentives become sufficiently strong for a growing population to intensify its land-use. This is corroborated by the relatively advanced agricultural intensification around Mwanza town.

The studies of Sukumaland and Machakos both show that rapid population growth in non-industrialized countries does not necessarily lead to irreversible land degradation and poverty. However, an understanding of the dynamics of agricultural production systems is necessary in developing relevant and acceptable policies and technologies aimed at improving the sustainability of the various land-use systems.

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