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Changing land-use patterns and farming strategies in the degraded environment of the Irangi Hills, central Tanzania

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Abstract

The approaches adopted by local farmers to put the degraded landscape of the Irangi Hills in central Tanzania to productive agricultural use are analysed. The area has been extensively affected by severe soil erosion, thereby reducing its potential for agriculture. While soil erosion in the upper and middle reaches of the slopes has resulted in extensive gullies, sedimentation in the lower reaches has created extensive sandfans and buried some of the fertile, clayey soils.

The changes in the present land-use practices were assessed by means of group discussions and transect walks, household interviews, field observations, and by archival research. The results of the study indicate that farmers have responded to the evolving land degradation by using more intensive and more productive forms of land-use. Crops are grown in diverse mixtures, aiming at increasing farm productivity and avoiding the risk of crop failures. Many farmers have also responded to land degradation by employing on-farm conservation practices such as ridge cultivation and tree-planting. There has also been a general shift from cultivation and settlement on hillslopes to less steep, middle and lower pediments and footslope areas.

Land-use patterns have constantly changed over the last few decades. One major intervention to try to rehabilitate the worst degraded areas came in 1979, when all livestock were evicted. The quarantine still remains, but since the early 1990s free-grazing livestock have gradually, but illegally, been brought back into the area. Although the return of livestock has increased the availability of manure, it is likely to reverse the trends of ongoing land recovery. To complement the limited availability of animal manure more than 85% of farmers make and use compost to fertilise fields close to homesteads. Evidence is also presented to demonstrate that farmers have been quick to grasp whatever chances they had to make use of new land-use opportunities. When some of the sandfans in the area stabilised, following soil-conservation initiatives, farmers immediately realised that there were new niches in the landscape that could be utilised. Today the total cultivated area has increased considerably, compared to the early 1970s, when intensive conservation efforts were begun.
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Keywords: Soil degradation; Farming strategies in degraded lands; Land-use changes; Agricultural intensification; Utilisation of rehabilitated lands; Central Tanzania

1. Introduction

The Irangi Hills (Fig. 1) are located in Kondoa District in the semiarid, central part of Tanzania situated at an altitude of 1200–2000 m above sea level. They are inhabited by the Rangi people. The Hills enclose a 1256-km^2 area known as the Kondoa Eroded Area (KEA). The KEA is a recent administrative delimitation of a major land rehabilitation programme, the Dodoma Region Soil Conservation Project (HADO). The project was instituted in 1973 and is still operative, though currently with very meagre resources at its disposal. The area has been extensively affected by severe

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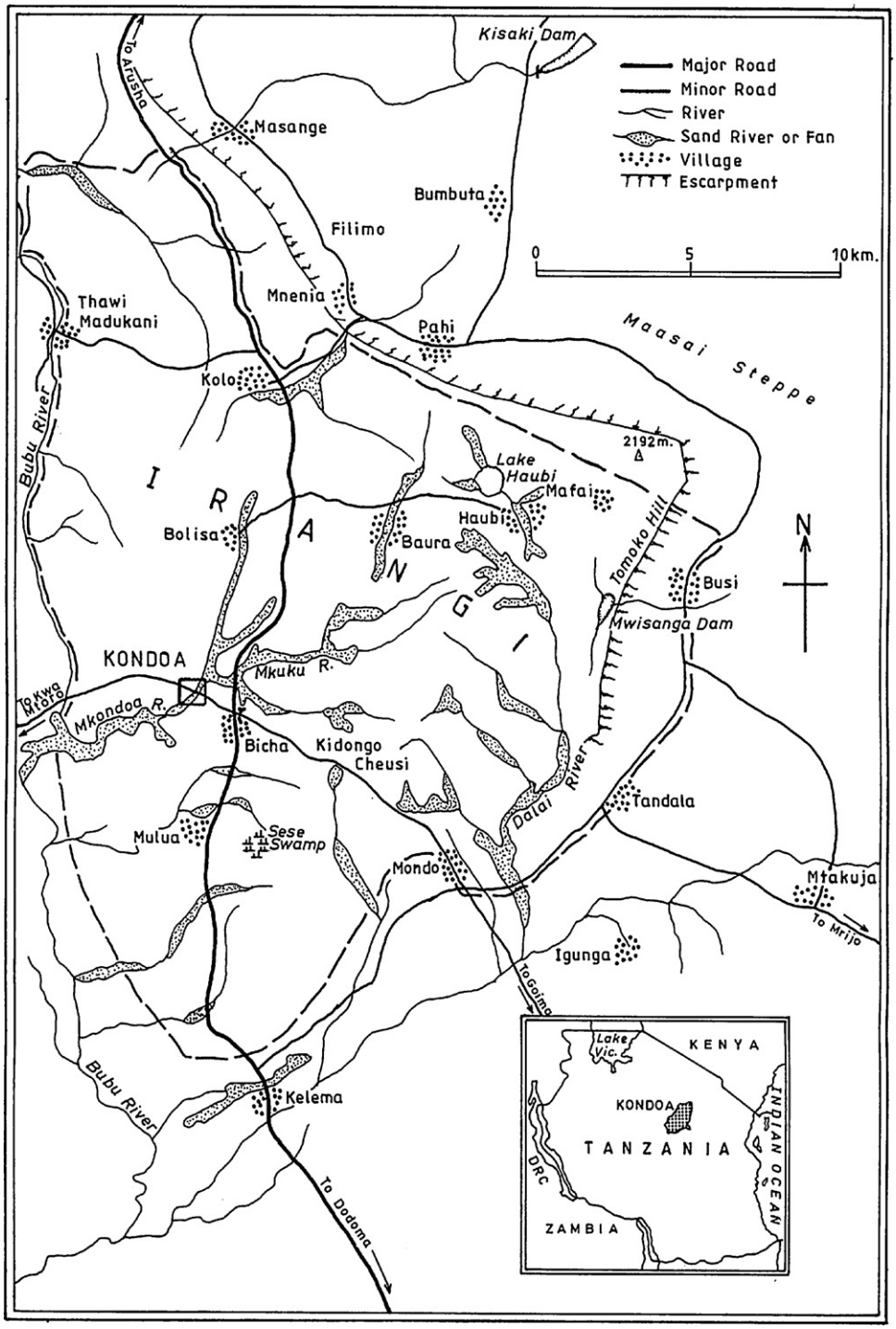


Fig. 1. Map showing the Irangi Hills—all the mapped area is within the KEA. The Irangi Hills stretch from the central parts of the district towards the north and north-west. To the east, they are bounded by an escarpment below which the plains of Lower Irangi and the Maasai steppe are situated. Isolated hills dot the plains. Slightly less than 10% of Kondoa District is taken up by the so-called KEA, a badly degraded area in the hills where comprehensive land-rehabilitation activities have been tried out since the 1930s. The studied villages, Haubi and Mulua, are respectively, located in the elevated north-east with a sub-humid climate, and in the lower south-west with a semiarid climate. Haubi is more severely eroded than Mulua and characterised by gullies as deep as 20 m. During the destocking exercise in 1979, all animals were evicted from Haubi, while the less severely eroded Mulua was only partially destocked. The insert shows the location of the Kondoa District within Tanzania where the Irangi Hills are located.

soil erosion, creating a landscape of rocky upper slopes with thin soils and lower pediments with thick colluvial deposits, where gullies can be as deep as 20 m. Low-lying areas are characterised by sandfans and sand-choked rivers. On the higher parts of the slopes, the soils are coarse and stony, whereas at lower levels they show finer texture (Payton and Shishira, 1994; Shishira and Payton, 1996). Valley floors have been subjected to recent aggradation as a result of

sedimentation following accelerated erosion higher in the catchments and most likely also due to older erosion episodes caused by natural factors, including climatic changes in earlier historical times. The alluvial sands and the exposed subsoil on pediment mid-slopes both have small organic-matter content, unstable soil structure, low nutrient holding capacity and poor crop performance (Shishira and Payton, 1996; Kangalawe, 2003).

The objective of this paper is to assess in what ways farmers in the Irangi Hills have altered their land-use practices in response to soil degradation and increased pressure on the land resources. The analysis is based on a survey conducted in two villages, Haubi and Mulua, between 1997 and 2001. The paper also draws on various studies carried out throughout the 1990s by researchers working within the multidisciplinary ''Man-Land Interrelations in Semi-Arid Tanzania (MALISATA)'' research programme (Christiansson et al., 1991; Kikula, 1996).

Many factors are thought to have contributed to the soil-erosion problem in this area. The landscape is tectonically active and crustal movements have probably influenced the processes of soil erosion (Eriksson, 1998). The rainfall pattern exhibits high spatial variability, ranging from about 600 mm/year in the lower areas to around 900 mm/year in the higher parts. The Mulua and Haubi villages fall under the former and the latter rainfall regimes, respectively. Most of the rainfall occurs in short-duration storms with great eroding power (Christiansson, 1973; Ngana, 1990).

Soil degradation is an important problem in ecologically vulnerable semiarid regions, and agricultural exploitation easily results in soil crusting and deteriorated soil structure, mainly due to loss of organic matter (Lal, 1991; Chan and Hulugale, 1999; Kushwaha et al., 2001), leading to reduced rainwater infiltrability and lowered water-holding capacity (Falkenmark and Rockström, 1993; Boli Baboule and Roose, 1998). In the Irangi Hills human activities, such as cultivation on steep slopes and extensive grazing, have accelerated soil erosion. Some of the erosion features seen today predate human occupation and arose in during wetter periods in the Pleistocene (Eriksson et al., 2000). Also iron-smelting, perhaps a few hundred years ago (Eriksson et al., 2000), demanded wood as a source of energy and initiated deforestation, which is likely to have triggered erosion in certain locations. The long-distance trade of the 19th century that also affected the Kondoa area possibly meant that more land was opened up to produce food for the caravans (Mung'ong'o, 1995) and later for the troops during the 1914–1918 war (Christiansson, 1981). These processes are thought to have contributed to the serious land degradation registered in the area.

In the late 1960s, Tanzania's former President Nyerere advocated a change in the traditional settlement pattern to facilitate the provision of public services (Nyerere, 1967). This was implemented through the villagisation programme of the mid-1970s. People were moved away from scattered settlements, where the natural vegetation later recovered, and concentrated in other areas where the pressure on land increased. This concentration of rural population had significant consequences for land degradation in many parts of the country (Kikula, 1997), including Kondoa District (Östberg, 1995). However, farmers today find ways to produce considerable amounts of food despite the dramatic land degradation characterising large parts of the Irangi Hills.

The traditional land-use system of the Hills encompassed both crops and livestock. The crops included bulrush millet, sorghum, finger millet, lablab and beans. Livestock (mainly cattle, sheep and goats) played an important role as an insurance against crop failures and as source of manure and milk and were vital for building up economic and social relationships (Kesby, 1982). Since the 1950s livestock have also become an important source of draft power (Mung'ong'o, 1995). Earlier studies showed that in the 1970s, about 25% of households owned livestock (Mung'ong'o, 1995; Östberg, 1995). The stockowners often redistributed their livestock to non-livestock-owners as part of the management system. This meant that many non-livestock-owners also benefited from milk and manure. Dependence on livestock changed with the prohibition (in 1979) of grazing as part of the soil-conservation measures.

The Irangi Hills have been a focus of land rehabilitation attempts since the colonial days, although these measures met with varying degrees of success, and many were abandoned after independence (Christiansson, 1988; Mung'ong'o, 1991, 1995; Östberg, 1995). The continued land degradation after independence caused the Tanzania government to reinitiate soil-conservation activities in the early 1970s by the establishment of the state-run Dodoma Region Soil Conservation Project (HADO) in 1973. A particularly drastic measure was to evict all livestock from the 1256-km^2 KEA in 1979. By that time the Irangi Hills had about 90,000 heads of livestock, rendering many places devoid of vegetation because of intensive grazing. This move was reinforced by planting trees and grasses and the construction of contour bunds, allowing for natural re-vegetation and the recovery of the severely eroded areas. However, since the eviction of livestock the land use has become dominated by crop cultivation. The planting of elephant grass on sandy riverbeds and sand-depositional areas and the natural vegetation recovery following destocking resulted, for instance, in stabilisation of the extensive sand accumulations. These areas are now successfully used for cultivation.

The changes and emerging in land-use patterns will be presented and discussed under three main headings: land degradation and land-use patterns; intensification of the land-use system; and expanding cultivation into new areas.

2. Description of the study areas

The study areas, the Haubi and Mulua villages (Fig. 1), are located in the north-east and south-west of the Irangi

Table 1
Some characteristic features of the study areas[a]

Characteristic features	Haubi	Mulua
Latitude/longitude	4°44′-4°50′S, and 35°52′-36°00′E	4°56′-5°00′S. and 35°42′-35°49′E
Mean annual rainfall (mm)	500–2000	400–1200
Temperatures	16–23 °C	19–23 °C
Evaporation	2000 mm	2000 mm
Altitude (m a.s.l.)	1620–2010	1200–1545
Dominant natural vegetation	Savannah woodland (miombo) dominated by *Brachystegia* sp.	Wooded grassland dominated by *Acacia* sp.
Main soil groups	Arenosols, Fluvisols, Cambisols, Lixisols, Gleysols, Luvisols, raw sands	Arenosols, Fluvisols, Calcisols, Leptosols, Cambisols, Lixisols, Gleysols, Luvisols, raw sands
Population (1999)	10,260	1680
Average cultivated area (hectares per household)	2.1	2.4
Main crops	Maize, finger millet, sorghum, pigeon peas, beans, cowpeas, groundnuts, lablab, sweet potatoes, cassava, sunflower	Maize, sorghum, bulrush millet, finger millet, cowpeas, pigeon peas, groundnuts, beans, sweet potatoes, cassava, sunflower

[a] Rainfall, temperature and evaporation figures for Mulua are represented by those from Kondoa Town, 7 km to the north. *Source*: Kangalawe (2001).

Hills, respectively. Haubi, northeast of Mulua, is at higher altitude and usually receives more rain (Table 1). The mean monthly values are shown in Fig. 2. Haubi is sub-humid, while Mulua is semiarid, but the long-term rainfall pattern for these two agro-ecological zones shows high variability between years (Fig. 3).

The vegetation in the Irangi Hills is dominated either by degraded low trees and shrub savanna, or savanna woodlands, with localised patches of semi-evergreen, montane forest, such as the Mafai Forest (Lyaruu, 1998; Eliapenda, 2000). The low trees and shrub savanna are found in the drier, south-western parts which are dominated by Acacia and *Commiphora* sp., and grass species such as Hyparrhenia and *Themeda* sp. The degraded savanna woodland is found in the moister north and north-east and is dominated by *Brachystegia* sp. (Banyikwa et al., 1979; Yanda, 1995; Backéus et al., 1994; Lyaruu, 1998; Eliapenda, 2000).

The major soil groups are presented in Table 1. Soils types change down the slope forming catenary sequences (Payton et al., 1992). On the higher slopes, soils consist largely of the stony residue left after severe erosion. The low-lying midslopes or backslopes are characterised by moderately sloping pediments that cut across deeply weathered rocks or saprolites. The major soil types here are also greatly eroded, consisting of truncated Chromic Lixisols, Luvisols and Regosols on the upper pediments and Ferric and Chromic Lixisols on the middle to lower pediments. Albic Arenosols and Gleysols occur on the

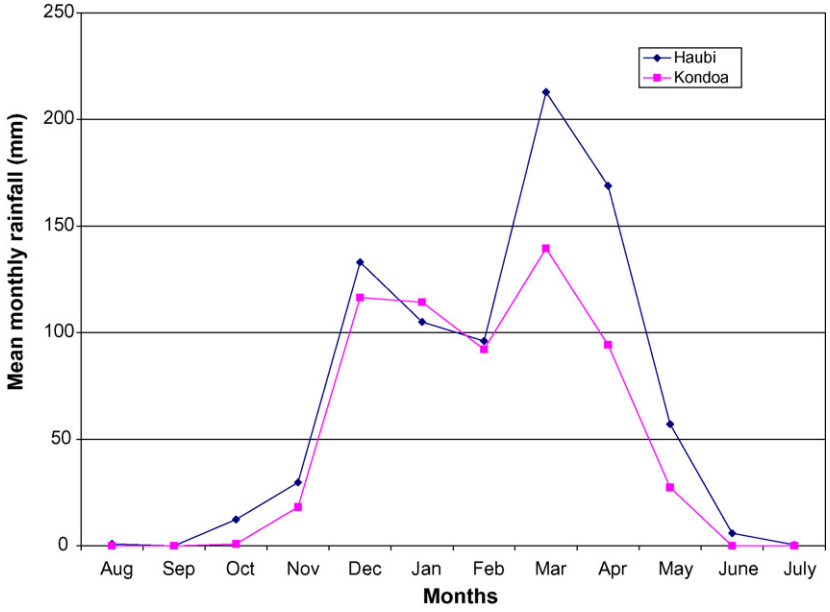


Fig. 2. Mean monthly rainfall for Haubi and Kondoa, representing sub-humid and semiarid, agro-ecological conditions respectively. The period between June and October represents the dry season, when in general cultivation is restricted to small gardens in the moist *mbuga* areas in Haubi and in sandy riverbeds in Mulua. Diagram based on rainfall records for the years 1959/60–1989/90.

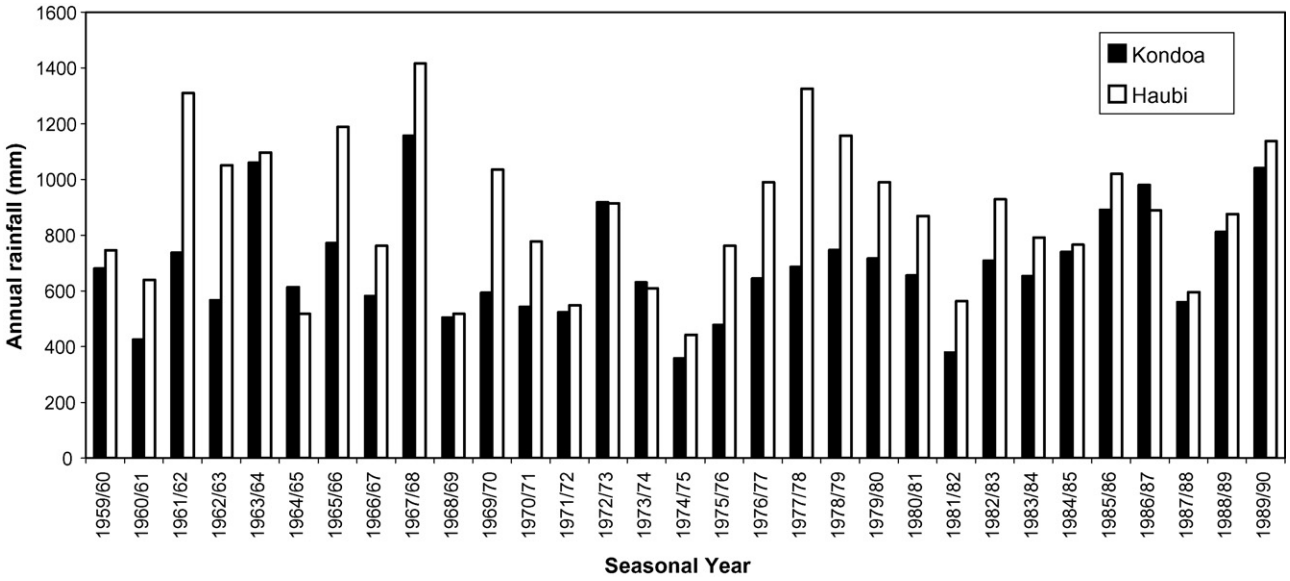


Fig. 3. Annual rainfall for Kondoa Town and Haubi Mission stations, representing semiarid and sub-humid conditions respectively. Mulua village is within the same agro-ecological zone as Kondoa Town and thus the rainfall pattern of Kondoa Town represents also Mulua's long-term, rainfall pattern.

footslopes, and Haplic Arenosols and Vertisols on the toeslopes. On the upper and middle pediments, extensive sheet erosion has in some places removed 1–2 m of soil (Payton and Shishira, 1994). The slopes are dissected by numerous gullies, which locally have coalesced to form badlands.

3. Methods

This study involved group discussions, wealth-ranking, household interviews and field surveys, as described below, complemented by a review of secondary data sources. The range of methodological approaches used aimed to capture as much local knowledge as possible, which needed more descriptive qualitative data, while at the same time addressing the ongoing debates about soil erosion/land degradation.

3.1. Participatory techniques

Detailed discussions were held with farmers between 1997 and 2001 regarding soil degradation, different soil/land types in the area, agricultural history, crop cultivation patterns and livestock husbandry, how they perceived changes in soil-fertility status and how these perceptions influenced their land-management practices. Special attention was given to the driving forces that have caused changes in these practices. A participatory, wealth-ranking exercise was carried out with small groups of farmers, as described by Grandin (1988), to identify patterns of socio-economic stratification, as locally perceived, to assess variations in land-management strategies between farmers with varying access to resources. Wealth-ranking in the studied villages revealed that 13% and 11% of households were classified as being wealthy (wasungati) in Haubi and Mulua respectively and, in the same order, 60% and 52% were considered as being of average wealth (watu kati), and 27% and 38% as poor (wakiva).

3.2. Field surveys

The field surveys were conducted between 1997 and 2001, and involved a series of transect walks with groups of farmers (cf. McCracken et al., 1988) to map the different soil/land types identified by farmers during group discussions and interviews. Here farmers presented their understanding of soil concepts, the names they use for different soils, and how they view soil-degradation processes and the vegetation types they discern in their respective areas. A description was also given of how, along selected transects, different parts of the landscape are used. Special importance was attached on the management implications of different locations along the catena.

3.3. Household interviews

The information from the participatory analyses was complemented with data collected during detailed household interviews, over the same period, involving about 13% of farmers from each village. A stratified random sample of 198 heads of households was selected from a list of all village households specially prepared for this study. The age of the selected heads of households ranged between 22 and 90 years, with an average age of 51 years, and comprised 65% men and 35% women.

The structured questionnaire survey focused on the agricultural history of the area, the current land-use pattern,

soil-fertility changes and management strategies for the different soil/land types, their potentials and limitations for agricultural production, and socio-economic variables affecting agricultural production, such as access to the different land types and inputs like manure and fertilisers.

4. Land degradation and the land-use pattern

4.1. Perceptions of soil degradation

The studied villages exemplify areas where natural resources are under strong pressure. Soil degradation is a universally perceived problem in these villages. Interviewed farmers explained degradation as loss of surface soil through sheet erosion and rilling, as creation of deep gullies and badlands and as decline in soil fertility. Farmers interviewed in Mulua and Haubi villages, 75% and 92% respectively, considered soil degradation a serious problem in their vicinities. Older farmers further recalled how some small gullies had expanded, leading to decreased arable land and forcing some people to move their settlements to new areas. The remaining percentages perceived soil degradation as a natural part of the landscape they have inherited. Local oral traditions indicate that, as soils on the upper slopes became exhausted and degraded, the early inhabitants moved their crop fields from the upper pediments and hillslopes into the middle and lower pediments in the search for good soils. Settlements also came to follow this relocation movement down the slopes and most of them are today found on the middle and lower pediments (Kikula and Mung'ong'o, 1993).

Interviews with farmers also indicated that soil fertility has declined progressively in continuously cultivated fields. Farmers' accounts are in agreement with studies in other parts of the tropics, which reported gradual yield decline under continuous cultivation (Ruthenberg, 1980; Tsunekawa et al., 1997).

Scarcity of good arable land in the Irangi Hills has been reported as a severe problem since the 1940s, due to both soil degradation and population increases. The present study has identified patches of so-called ''good lands'', including several variants of the local Lusanga group (e.g. consisting of the Arenosols and Calcic Chernozem/Calcisol Intergrades) in the colluvial footslopes and toeslopes, Nyika (Eutric Fluvisols) in the valley bottoms and Kinakana (Gleysols) in seasonally waterlogged areas and on lacustrine terraces (Kangalawe, 2001). They also include uneroded areas with several variants of Lixisols (locally known as Ikunduse) in the middle to upper pediments. However, these good-quality lands are not only scarce but also fragmented. This has led some people, particularly young farmers, to voluntarily migrate and establish themselves east of the Irangi Hills or outside the district, as long as it was possible to find arable land. Forest clearings and construction of dams on the plains, instituted by the colonial government in the late 1920s and the following decades, eased the movement of people from the Hills (Fosbrooke, 1950/51; Madulu, 1999).

Today farmers in the Irangi Hills recognise and acknowledge that as a result of soil-conservation efforts, particularly the expulsion of livestock in 1979, there is less runoff and erosion, and more land is now available for cultivation.

4.2. Land-use patterns in the study areas

There are two notable differences in the land-use pattern between the two studied villages, the role of livestock and the types of crops grown. In Mulua village, farmers still keep free-grazing livestock. Here only the eastern part of the village land was severely eroded and involved in the destocking exercise. In Haubi all domestic animals were evicted, except for draught animals that were and still are brought in during the cultivation season. Mulua farmers thus continued to have access to manure and other animal products, but the problem of degradation was transferred to the western reaches of the village, where grazing pressure increased.

Overall, the eviction of livestock resulted in an impressive vegetation recovery, followed by a reduction in runoff and soil loss in most of the KEA (Mbegu, 1996; Kikula, 1999). However, the exercise is argued to have denied the people such important products as milk and manure (Kikula, 1999). To solve this problem a stall-feeding regime was introduced in 1989 (Ogle et al., 1996). Records found at the veterinary office in Haubi village showed that by July 1999 a total of 133 households, about 8% of the village's households, were keeping stall-fed animals, while there were none in Mulua village (see Section 5.2).

Crops also differed between the two villages. Bulrush millet is widely grown in Mulua, is not grown in Haubi village, although about 13% of Haubi farmers planted bulrush millet outside the village, in the Lower Irangi, during 1996–2000 (see Table 2). Maize is grown in both villages, but in Mulua, production is less than that of the drought-resistant bulrush millet. In Haubi, which lies within the sub-humid area designated as ''Maize Zone'' (KDA, 1982), maize is the most important crop; and farmers here are more likely to have used inorganic fertilisers during the 1980s to early 1990s. Where fertilisers (e.g. urea) were used in maize, yields almost doubled, but no significant response was observed in bulrush millet (KDA, 1993).

Farmers in Mulua advanced three explanations for not using inorganic fertilisers—that fertilisers are not available when needed, that they are too expensive and that many farmers dislike inorganic fertilisers. They claim that inorganic fertilisers result in bad crop performances, particularly in dry years. Similar farmer opinion has been reported from other semiarid parts of Tanzania (Budelman, 1996; Kaihura et al., 1999; Shao, 1999).

Table 2
List of the main crops currently grown in the studied villages, the number of crop varieties and the percentage of farmers growing these crops

Crop	Scientific name	Number of varieties	Uses[a]	Percentage of farmers growing the crop	
				Haubi ($n = 142$)	Mulua ($n = 56$)
Cereal crops					
Maize	Zea mays	8	F, C	97	100
Sorghum	Sorghum vulgare	10	F, C	86	88
Finger millet	Eleucine coracana	4	C	89	63
Bulrush millet	*Pennisetum typhoides*	3	F	13	86
Wheat	*Triticum* sp.	2	F	2	0
Leguminous crops					
Pigeon peas	*Cajanus cajan*	5	F, C	94	73
Beans	*Phaseolus vulgaris*	5	F, C	92	61
Cowpeas	*Vigna unguiculata (sinensis)*	5	F, C	62	80
Groundnuts	*Arachis hypogea*	3	F, C	53	70
Lablab	*Lablab niger*	2	F, C	39	7
Bambara nuts	*Voandzeia subterranea*	3	F, C	8	18
Garden peas	*Pisum sativum*	1	F	10	0
Grams	*Vigna aureus, V. mungo*	1	F, C	0	5
Root crops					
Sweet potato	*Ipomea batatus*	7	F, C	47	25
Cassava	*Manihot esculenta*	5	F, C	31	20
Irish potato	*Solanum tuberosum*	1	F, C	19	0
Oil crops					
Sunflower	*Helianthus annuus*	4	C	39	57
Castor	*Ricinus communis*	1	C	2	5
Vegetables					
Cabbages	*Brassica oleracea*	1	F, C	18	7
Tomatoes	*Lycoperscon esculentum*	3	F, C	8	5
Amaranthus	*Amaranthus sp.*	2	F, C	0	11
Onions	*Allium cepa*	2	F, C	4	0
Fruit crops					
Banana	*Musa* sp.	2	F, C	20	0
Papaya	*Carica papaya*	Ne	F, C	NE	NE
Citrus	*Citrus* sp.	Ne	F, C	NE	NE
Other crops					
Pumpkins	*Cucurbita pepo*	4	F	8	5
Sugarcane	*Saccharum* sp.	3	C	18	4

[a] F, domestic use as food; C, for cash income; NE, not established.

Budelman and Van der Pol (1992) pointed out that, for sandy soils with low cation exchange capacity, low organic-matter content and low-activity clay, nutrient recovery from fertilisers is likely to remain low and therefore the use of fertilisers becomes uneconomical. It is not surprising therefore that, where manure continued to be available in the post-destocking period, as in Mulua village, farmers preferred the locally available manure to the expensive fertilisers.

5. Intensification of the land-use system

The degraded landscape of the Irangi Hills has experienced both intensification of land-use and expansion of agricultural land. Both are regarded as indicators of transformation of the agricultural systems (Hansen and Reenberg, 1998), often associated with degraded environments (Falkenmark and Rockström, 1993; Sanchez and Leaky, 1996). This section examines the ways in which farmers intensify their land-use practices, while Section 6 addresses expansion of agricultural land.

5.1. Crop diversification and intercropping patterns

Today a wide range of crops is grown in the study area, complementing the traditional bulrush millet, finger millet and sorghum. The idea of crop diversification was introduced on a broad scale in the 1940s. The colonial regime then required farmers to plant crops such as maize, cassava and sweet potatoes (Kesby, 1982). Sunflower and sesame were introduced in the 1960s as cash crops to complement finger millet, the most commonly grown cash crop. The wide range of crops now grown (Table 2) demonstrates how the farmers have tried to adapt to the environmental conditions through diversification. Crop

diversification and the keeping of livestock are risk-averse strategies followed by farmers in semiarid environments (Scott, 1994; Boesen, 1999; Madulu, 1999).

5.1.1. Expanding maize-growing

That the earlier bulrush-millet farming system of the Irangi Hills has today changed into a mainly maize culture, particularly so since the expulsion of livestock in 1979, is attributed to frequent bird-attacks on bulrush millet (Christiansson, 1988; Mung'ong'o, 1991; Kangalawe, 2001). The regenerating vegetation now provides suitable habitats for millet-eating birds such as weaverbirds (Quelea quelea). In several instances during fieldwork for this study, big flocks of Quelea quelea were found in bulrush-millet fields.

However, bulrush millet is grown in other parts of central Tanzania with dense vegetation, suggesting that decreased cultivation of this crop in the Irangi Hills is influenced by other factors. The farmers' stated reasons for the abandonment of this crop included also a change of taste among young people, low productivity of bulrush millet compared to maize, introduction of inorganic fertilisers that favoured maize-growing, attacks by insect pests in some years and, occasionally, unfavourable climatic conditions (particularly in very wet years).

The change of taste among younger people appears to have had a particularly important influence. Interviewed farmers pointed out that the young generation ridicule the bulrush-millet traditions. They assert that eating ''ugali'' from bulrush millet is ''old-fashioned'' and too heavy, comparing it to ''concrete'', and, consequently, they also dislike bird-scaring. Elderly people still like bulrush-millet meal because of its high satiety value, and they tend to grow it outside the village. The generational change of taste started in the 1960s when young people began to receive formal education and became exposed to outside influences. Hence maize meal has become their preference. The argument is reinforced by the higher productivity per unit area of maize.

Another probable reason why farmers changed to maize growing is marketing. There is a ready market for maize but not for bulrush millet. In Haubi there is an open market every Sunday. Observations during intermittent visits to this market between 1997 and 2001 have never recorded bulrush millet, while maize was always found. It appears that bulrush millet is a crop not regarded as belonging to the market, which is why none of the interviewed farmers mentioned any constraints in marketing this crop.

5.1.2. Intercropping

The survey in Haubi and Mulua villages in 1997–2000 found that almost all crop fields were intercropped. Farmers' reasons for practising intercropping are presented in Table 3. On pediment slopes, most intercrops comprised different combinations of either maize with finger millet, sorghum and sunflower or of sorghum with finger millet and/or sunflower. These cereals were also found intercropped with different combinations of legumes, such as beans, cowpeas, pigeon peas, lablab and groundnuts. In Mulua, bulrush millet was seen intercropped with sorghum, the shading effect of the cereals being minimised by planting at wide spacing. And cassava is occasionally intercropped with lablab and pigeon peas. In contrast, in the valley bottoms and seasonal watercourses, one finds combinations of vegetables, sweet potatoes, bananas and even (in the moister north-east) Irish potatoes. Where the intercropping practices involved pigeon peas, it was locally perceived to prevent post-harvest trampling of the land by grazing animals, since the crop remains in the field for a long time after other crops have been harvested.

Another local intercropping feature is the inclusion of trees planted for such purposes as timber, fuelwood, shade and the improvement of soil fertility (Barr, 1994). Mature trees have value and are thus considered by local farmers as capital assets representing savings. This is particularly important in the destocked areas, where there are relatively no cattle to be used as wealth.

The intercropping and/or mixed-cropping practised by farmers in the study area are an important strategy that farmers in other semiarid environments in Tanzania also employ to adapt to soil degradation and unfavourable climatic conditions (Boesen, 1999; Shao, 1999). In the studied villages it is common to find more than four different crops growing in the same field. These practices are also supported by studies from elsewhere in the world (El-Swaify et al., 1985). In Haubi and Mulua villages, it is a common occurrence to find cereal–cereal intercropping patterns, which are also dotted with pulses. The explanation by local farmers concerning this practice is that it spreads the risks of crop failure and maximises the use of available land. Another advantage of intercropping practices, though not mentioned by farmers, is that they also help to control crop

Table 3
Reasons for practicing intercropping in the Irangi Hills, expressed in the percentages of farmers reporting each reason

Reason for intercropping	Percentage of farmers reporting the reason	
	Haubi ($n = 142$)	Mulua ($n = 56$)
Spreading risks, increasing food security and diversification of income sources	56	95
Crops doing well together (compatibility aspects)	56	80
Optimising the use of available land (due to land scarcity)	39	13
Soil-fertility management (where leguminous crops are involved)	3	20
A traditional practice	3	0

pests and diseases by impeding the movement of disease organisms or predators within the agro-ecosystem (Ruthenberg, 1980; De Steenhuijsen Piters, 1995).

5.2. Intensified livestock-rearing: a fumbling start for stall-feeding

With the expulsion of free-grazing livestock from the KEA in 1979, the land-use system changed from agropastoralism to reliance on crop cultivation. However, most livestock owners continued to keep livestock outside the enclosed area, thus retaining the social and economic advantages of livestock for the household. In addition, a pilot stall-feeding project was introduced in the KEA in 1989 (Ogle et al., 1996) with support from a SIDA/SAREC-financed, livestock project entitled ''Development of Feeding and Management Systems for Stall-fed Improved Dairy Cows on Smallholdings in the HADO Areas'' (Rehnström, 1999). According to a HADO evaluation report, only about 100 KEA farm families were participating in the project by 1995, each ideally keeping a maximum of three grade cows or crossbreeds (SIDA/MTNRE, 1995).

Official project records, available at the Department of Agriculture in Kondoa Town, indicate that the number of farmers keeping the stall-fed cows had declined to 82 by February 1999, while 76 farmers had adopted the stalling of dairy goats. High initial costs in establishing stall structures and difficulties in acquiring improved animals, together with high labour requirements, are among the constraints that face many farmers, particularly from poor households. It was for these reasons that those who joined the stall-feeding project were mainly the wealthy farmers. Wealth is closely associated with age, and at the initial stages of the project the adopters were people over 48 years of age (Kerario, 1996). However, the present study found that today younger farmers below the age of 30 are keeping stall-fed cattle with income obtained from small businesses and/or selling crops. Nevertheless, the numbers of improved stalled animals have remained small.

Though more farmers are becoming involved in stall-feeding, most of them keep local breeds instead of the improved ones that are not readily available. Records at the veterinary office in Haubi indicated that by July 1999 Haubi village alone had a total of 394 stalled cattle, of which only 16% (i.e. 62 animals) kept by 19 farmers were improved or crossbred cows. A total of 133 farmers, representing about 8% of Haubi households, were involved in keeping stalled animals (Kimaryo, 1999, personal comm.). Thus farmers are increasingly, though informally, getting involved in the stall-feeding. Farmers who have taken up stall-feeding report several advantages: (a) sales of milk and sometimes meat increase income; (b) fodder collection is more flexible in terms of time; (c) cessation of herding duties frees up much time for other activities; (d) animals housed in a cowshed grow faster and are healthier than those freely grazing.

Health support is a major problem, since external funding for the project has now disappeared and the risks are higher as long as medicines are not available. So trials with stall-fed goats, whose risk premium is smaller, have also been attempted in a few villages (Baura, Bolisa, Igunga and Kolo), and by February 1999 there were 240 dairy goats and 76 farmers were involved in the project (Msaka, 1999). Although stall-fed goats can also be found in some other villages outside the trial project area, it is mainly on the individual farmer's initiative.

Although crop cultivation has dominated the KEA land-use since 1979s, a steadily growing number of free-grazing livestock has infiltrated the destocked area during the 1990s, despite the formal prohibition (Mung'ong'o, 1995; Kangalawe et al., 1999; Östberg, 2000). The informal return of livestock is a satisfactory sign to many in the Irangi Hills who are of the opinion that the degraded land has now recovered. Interviews with elderly farmers in Haubi and Mulua indicate that farmers nurture the desire to be allowed to graze their livestock freely and return to their traditional means of livelihood. This is an emerging constraint on stall-feeding practices, since with the increasing number free-grazing animals, a shortage of fodder could arise; and few farmers seem prepared to carry fodder and water to their animals if others are allowed to graze.

5.3. Increased use of manure and compost

Responses at interviews in Haubi in 1985 (Östberg, 1986) and in the nearby villages of Mafai, Baura and Bolisa in 1994 (Kangalawe, 1995) point to a long tradition of manure use in the Irangi Hills. During interviews within the present study, several farmers noted that, although livestock were numerous prior to 1979, not many households actually owned livestock. Those who did often had large herds, and they were the ones that used most of the manure. However, to the extent that animals were often distributed among relatives and/or friends following a trusteeship system (Mung'ong'o, 1991; Östberg, 1986), the access to some manure was further distributed. Another option for those who did not keep any animals was to buy small amounts of manure. A pile measuring 2–3 m × 2–3 m and about 1–2 m high could be bought with one or two goats, and three such piles (approximately 2 tonnes) would be sufficient to fertilise 1 ha. This amount is, however, far below the 5 tonnes/ha recommended for Dodoma region (Mowo et al., 1993) and the annual manuring rate of 7.5 tonnes/ha recommended by agricultural officers since the colonial times (Kesby, 1982).

Farmers in the study area noted that they were unable to use manure widely, as most of them either have no cattle or have insufficient manure. Even so, the proportion of KEA farmers reported to have used manure seems to have increased in recent years, from about 67–75% in the mid-1990s (Kangalawe, 1995; Eklund, 1996) to about 95% at

Table 4
Fertility-management and soil-conservation practices and percentage of respondent farmers reporting that they have used them in the two studied villages

Fertility management and/or soil-conservation practice	Percentage of farmers	
	Haubi ($n = 106$)	Mulua ($n = 40$)
Manure application	95	95
Compost or residues left in fields	92	68
Intercropping and crop rotation	85	93
Cultivation ridges	86	90
Contour bunds for erosion control	86	90
Planting trees and grass	86	88

present (see Table 4). However, the average amounts used were very small, ranging from 0.4 to 1.2 tonnes/ha every other year (Kangalawe, 1995). The manure was obtained from animals that were at the time grazing permanently within the KEA, despite the grazing restrictions.

A livestock survey indicated that by the end of the 1998/99 growing season, Mulua village had 1000 free-grazing cattle, 1300 goats and 116 sheep, while Haubi had 618 cattle, 140 goats, 30 sheep and 38 pigs (KDA, 1999). The numbers of cattle recorded for Haubi are those legally coming into the village as draught animals. Together with the 394 stall-fed animals reported earlier, this village has more than 1000 cattle, additional to those brought in without permission. Certainly the reported goats and sheep are illegal, because they are not brought in as draught animals.

Farmers' responses indicated that manure is applied on a rotational basis and, depending on its availability, to each plot once in 2–3 years. Either it is broadcasted before ploughing, where adequate amounts are available; or it is put into the planting hole with the seed, where amounts are inadequate. Elderly farmers in both villages believe that manure applied in one season remains beneficial to crops in the succeeding growing season. The crop benefits, they argue, from a residual effect. A similar argument was also reported for the Irangi Hills and Lower Irangi areas by Dejene et al. (1997), and in other parts of Africa (Meelu, 1981; Duxbury et al., 1989; Eyasu, 2000).

Farmers' emphasis on the role that manure plays in sustaining agricultural productivity reflects a general concern that soils in the area have low natural fertility. In interviews they often mentioned in the Hills that "without manure you will not get anything in such a degraded environment". Farmers' views seem to be shared by scientific analyses (Kaihura et al., 1999; Van Wambeke, 1992). However, farmers also claimed that fertilisers destroyed the soil. They argued that, if there are not sufficient rains, the fertilisers "burn the crops", while, if one stops using them in a field to which fertilisers have once been applied, then "all the crops sink", meaning they show stunted growth. This may partly be due to lowering of soil pH associated with use of nitrogenous and phosphatic fertilisers (cf. Van Wambeke, 1992; Kaihura et al., 1999). In the 1980s many farmers in the Irangi Hills used fertilisers; nearly 50% of Haubi farmers reported that they had used fertiliser at that time. This was the period following destocking when fertilisers were more easily available. However, with the high prices since the mid-1990s, farmers can no longer afford to buy them.

Following destocking in 1979, the use of animal manure has gradually been complemented by compost-making (Östberg, 1986; Kawa, 1993). In the present survey, 92% and 68% of farmers in Haubi and Mulua respectively indicated that they had used compost on some of their crop fields, possibly reflecting the greater shortage of animal manure in Haubi. Compost is prepared in several ways, either in heaps on the ground or in purposely dug pits (c. 2 m long, 1.5 m wide and 1 m deep) and/or in cultivation ridges (in situ composting), using crop residues, household waste, droppings from poultry, grass and branches. Where pits are used, water is added before the pit is covered with soil and the material is left to decompose. After 1 year the compost is ready for use. Although the number of farmers making compost has increased in recent years, the amounts produced by individual farmers are very small. It is mainly fields close to homesteads that receive the compost. Many farmers also use crop residues for mulching. The straw is placed in the old furrows and later covered by soil dug from either side of the furrow, thereby forming a ridge, in which the straw decomposes. The ridges exchange positions each year, thereby distributing the mulch in the field (Östberg, 1986).

5.4. On-farm soil conservation

Cultivation using contour ridges was introduced more than half a century ago as one of the soil-conservation approaches for the Irangi Hills recommended by the colonial government (Tanzania, 1977; Kesby, 1982). Today almost 90% of the farmers make cultivation ridges as part of the normal land-preparation routines (Table 4). The cultivation ridges are arranged along the contours to arrest surface runoff and are often planted with crops, such as sweet potatoes. Larger contour ridges are often placed at intervals down the slope. Meanwhile, some of the old contour ridges reinforced with sisal, prepared during colonial soil-conservation campaigns, are now being broken down for cultivation. Farmers want to take advantage of the accumulated soil fertility. The fertility characteristics of these conservation structures are being analysed and will be discussed in a separate report by the first author.

Looking at the Irangi Hills today, one can see a well-vegetated landscape. Reports dating from the first half of the 20th century tell of densely cultivated areas but also of a largely barren landscape. In 1944, Father Yerome, of the Haubi Catholic Church, introduced cypress (*Cupressus* sp.) and Grevillea robusta trees into the area, as well as African mahogany (Khaya nyasica) from Kilimanjaro. Since then, many people in Haubi have been planting not only these trees but also orange, lemon, mango and guava, activities

supported by the HADO project (Mbegu, 1988). In addition, local by-laws prohibit felling green wood from the woodland without permission, thereby encouraging farmers to plant trees in their own farms.

On-farm conservation appears to be an attractive undertaking among farmers in the study areas. Farmers are improving their land through tree-planting, applying farmyard manure and compost, and constructing contour bunds. Where there is lack of investment, it is due more to poverty than unwillingness to invest. Further, the idea of demarcating village boundaries encourages people to take more personal responsibility for the land, and to use it with a long-term perspective (Christiansson et al., 1993).

5.5. Trying new crops and planting techniques

Many farmers are trying new crops and/or new planting techniques. For example, one elderly farmer in Haubi village started growing wheat in 1994 on about 0.5 ha. After realising good results from the first season, he expanded his experiment into other fields (c. 2 ha), and by 1999 a few other farmers had emulated him. Wheat is the last crop to be planted, under-sown beneath crops like maize and sorghum, and it matures on residual soil moisture after the rains have stopped. Sowing comes at the time of low labour demand and, because this is relay-planting, it does not involve much tillage.

Another new technique is combining vegetables and sugarcane in Mulua riverbed sands, a soil locally known as Isare. One farmer in Mulua village owns a 0.1 ha plot in a riverbed in which he grows tomatoes during the dry season (in 1 m-deep pits) in between the sugarcane rows. He harvests 4 debes (a debe = a 20 litre container) of tomatoes each week (c. 80 kg) for 4 months, from October to January. Sugarcane also fetches a ready market, within the village and in the nearby Kondoa town. Another example of farmer initiative is the use of reclaimed gullies for growing sweet potatoes, and the actual reclamation of sand rivers (Östberg, 1986). These initiatives, as well as the increasing farmers' cultivated area, demonstrate how farmers first test new techniques on a small scale and then, when they are successful, expand them within a few years grown into new major activities.

6. Expanding cultivation into new areas

Migration beyond the Irangi Hills is perhaps the most direct reaction to the stress of the declining land-resource base due to degradation and population pressure, while intensification and local expansion of cultivated area are other farmer responses. As a result of land rehabilitation initiatives the cultivated area in the Irangi Hills has increased considerably (Mndeme, 1992; Mung'ong'o, 1995; Kangalawe, 2001). Such increase is attributed mainly to stabilisation of sandfans, narrowing of watercourses, and the cultivation of former dry season grazing areas, the wetlands. Although the total cultivated areas have expanded, there has been a considerable change in their spatial distribution, particularly during the last four decades. For instance, areas on the hillslopes, on which cultivation is prohibited, have reverted to natural vegetation (Kangalawe, 2001).

6.1. Cultivating the sandfans and riverbeds

The sandfans encompass the sandy soils locally known as Lusare (Kangalawe, 2001). These fans are reported to have been formed as a result of "recent" phases of accelerated soil erosion which began 200–900 years ago (Payton and Shishira, 1994). They consist of recently stabilised or still stabilising sands deposited mainly on the more gently sloping, lower pediments and low-lying sections of the landscape (Fig. 4). In some cases they overlie, to a depth of 2–4 m, fertile black clays that are now inaccessible to the roots of annual crops (Shishira and Payton, 1996). Farmers rank these sands lowest in fertility status among the soils commonly used for cultivation, although they are light and easy to work wet or dry. The main problems are the low content of available nutrients and the low moisture retention. Reasonable crop yields can be obtained only with sufficient use of manure or compost.

Such soils, which until recently appeared to have no agricultural potential, are now intensively cultivated. In the extensive sandfans of the lower pediments, the crops grown include maize, groundnuts, sorghum, pigeon peas, beans, sweet potatoes and cassava. Of those interviewed, 64% and 75% of Haubi and Mulua farmers respectively had at least one crop field in the sandfans, with sizes of fields ranging from 0.1 to 2.4 ha per household (mean 0.5 ha), and Lusare fans accounted for about 17.3% of the total land area cultivated by interviewed farmers. All this demonstrates not only the farmers' need for more land but also their initiative in exploiting all possible niches of the landscape

The riverbeds consist of unstabilised raw sands locally known as Isare, which is not even considered to be soil. Reduction in flash floods due to soil conservation initiatives by HADO have made these ephemeral watercourses accessible for growing crops, including sugarcane, sweet potatoes and vegetables. The vegetables are sold in local markets and are a good source of cash income. The established sugarcane checks runoff and enhances the stabilisation of these loose sands.

6.2. Putting former grazing areas into cultivation

According to elderly farmers, before 1979, livestock grazed in the low-lying parts of the landscape moister valley bottoms (mbugas) during the dry season and moved up on to the hillslopes and hilltops in the wet seasons (Fosbrooke, 1950/51). After 1979, some mbuga depressions that had previously been used for dry-season grazing became

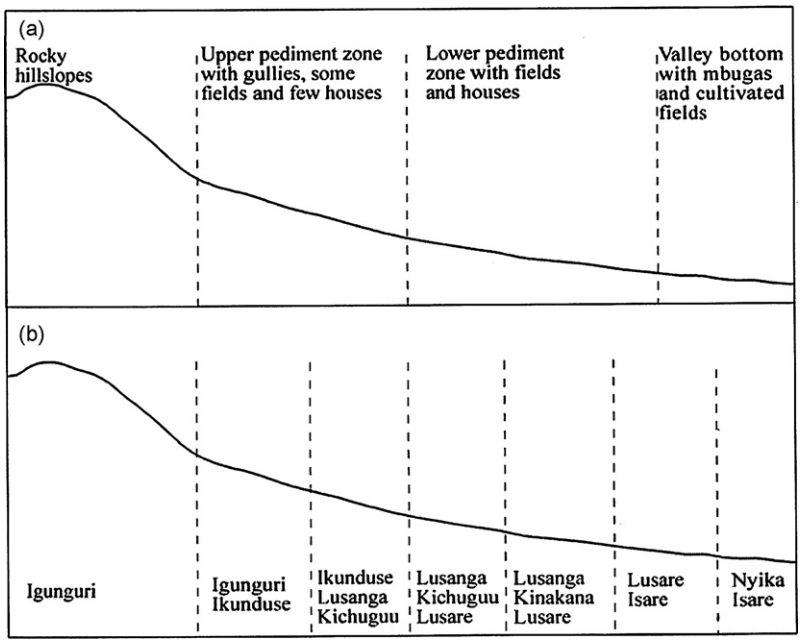


Fig. 4. Generalised soil catena, showing location of (a) different types of landscape and (b) main local-soil groups in Haubi and Mulua villages.

available for crop cultivation. In Haubi village, the mbuga is found along the seasonally inundated lakeshores, in the centre of the village area, while in Mulua the mbuga mainly occupies the Bubu River valley, in the west of the village (Fig. 1). In the Haubi basin, the mbuga depressions retain moisture for a larger part of the year, permitting the dry-season production of such crops as sugarcane, bananas, maize, beans, potatoes and vegetables.

In a soil-ranking exercise, farmers classified mbugas soils as the best in the area, and most of them do not use any kind of fertilisers or manure on this land type. In some places such as Kolo (Fig. 1), the mbuga was centrally distributed after destocking and allocated to all households (Kawa, 1993), but plots were very small, only about 0.2 ha per household. But in Mulua and Haubi it was different. In Mulua, acquisition of mbuga land in the seasonally swampy, western part of the village depended on pioneering individuals opening up their own fields. In 1997 and 1998, more than 70% of these farmers had mbuga plots and relied heavily on them for their livelihood. The Bubu river valley is wide and allows fairly large plots, about 1.1 ha per household. In Haubi, mbuga plots were acquired when farmers with land near the lake extended their fields into former grazing land on the lakeshore. Only 20% of interviewed farmers had an mbuga plot (average area only 0.4 ha), and mbuga land comprised only 14% of their cultivated area. However, Haubi mbuga plots are cultivated beyond the end of the rainy season; Mulua is drier, and mbuga cultivation there is limited mainly to the rainy season

The mbugas are a new option for cultivation, and farmers have been quick to exploit it. The drying up of Lake Haubi between 1994 and 1997 illustrates how quick farmers are to utilise such new options. When a new mbuga area appeared to be in the making, many people, particularly young farmers, immediately moved in and opened new fields in the dry lake bottom. This triggered resentment among the village environmental committee to the extent of prosecuting those who invaded the area. But after 3 years of drought, the 1997/98 season rains were unusually heavy, and the lake filled up, submerging all the crop fields within its borders. This closed all the crop fields within its borders – and closing all court cases! Nonetheless this event illustrates how important an issue land availability is in the study area.

6.3. Expansion of farmland

Shortage of good arable land has been a recurrent theme in reports on the Irangi Hills since the early 20th century. Despite the smaller population, the cropland was already intensely used. Fosbrooke (1950/51) pointed out that by the 1950s the population of the Irangi Hills was increasing at such a rate that every bit of land that could possibly be cultivated was kept under the hoe. However, when Fosbrooke wrote this, he was part of the colonial administration advocating drastic land-rehabilitation measures, which may well have coloured his description of the intensity of land-use. Nevertheless, his comments show that administrators believed that there was heavy pressure on the land even at that time.

Interestingly, there are signs that current land-conservation activities have had a significant impact on the availability of land for cultivation. The average areas cultivated by each household in the current survey were 2.1 and 2.4 ha for Haubi and Mulua respectively, although the range between the smallest and the biggest farms remained very wide, mainly reflecting socio-economic status. Nonetheless, the findings

suggest tangible benefits from the soil-conservation initiatives. The area can now feed more people than ever before, and produce is being exported to the growing food markets in Kondoa town, Dodoma, Arusha and Moshi (see also Mung'ong'o, 1995). However, although production has risen, the main constraints remain the low fertility (Kangalawe, 2001, 2003), the limited availability of both manure and/or fertilisers (needed especially for the sandfans), and the erratic rainfall pattern.

Farm size ranges widely, from less than 0.1 to more than 10 ha. Twelve percent of the households farm less than 1.2 ha, which very likely means that they have considerable difficulties in supporting themselves. There were also very notable differences between the two villages. Although arable land is clearly more abundant in Mulua, the proportion of households with small farms is higher there than in Haubi. A wealth-ranking exercise showed that wealthy households have larger farms than poor households. Haubi has a larger percentage of respondents in the ''wealthy category'' (13.4%) than Mulua (10.7%), while Mulua has more respondents than Haubi in the ''poor category'' (37.5% vs. 26.8%).

6.3.1. Means of acquiring land

Interviewed farmers mentioned five ways by which they acquired the land. Firstly, each of them had acquired at least one piece through inheritance from parents; but because even parental land was often already in small pieces, the redistribution to children further increases fragmentation. Secondly, about 67% of respondent farmers had acquired land by buying from other farmers within the village or farther away. The wealthier farmers can afford to buy the best pockets of village land, as well as very distant fields, while some poor farmers are pushed into marginal areas. Thirdly, about 34% of farmers have rented land from other farmers through arrangements such as sharecropping, assisting the landowner with farm operations or cash payment. Fourthly, some farmers (25%) in Mulua had been allocated between 0.2 and 0.8 ha of land during the villagisation campaign in the mid-1970s.

The fifth way of gaining land is by pioneering. In Mulua village, pioneering involves clearing fields across the Bubu river valley and farther to the west, outside the village boundary; in Haubi, it means clearing fields in the protected areas to the north and north-east of the village or moving to the Lower Irangi.

7. Conclusions

The presented analysis demonstrates major changes in land-use strategies over the last few decades. Scarcity of good arable land, due to soil erosion, has driven farmers to adopt various farming strategies, involving soil conservation, diversification of both types and varieties of crops grown, and growing crops in various intercropping patterns aimed at soil-fertility management. These practices have enabled farmers to spread the risks of crop failures and to make effective use of available land.

The small amounts of manure used point to a land-use system that is essentially nutrient-mining and whose sustainability may be questionable. Yet the common use of manure in the destocked villages like Haubi is surprising; and, when the farmers say they use manure, they come very close to admitting that they keep livestock illegally. It therefore seems that infiltrating, free-grazing cattle are becoming an important source of manure. The high percentage of farmers reporting that they have used manure demonstrates an increasing concern to improve soil fertility in order to produce sustainably.

In addition to intensification, farming strategies have included the expansion of arable land, practices that are aimed at adapting to degraded environments. The expansion onto sandfans and former grazing areas represents a significant change in land use, involving both a major reallocation of farms within the landscape and an increasing focus on land rehabilitation. Further, if soil-conservation initiatives are sustained, those parts of the landscape involved will provide scope for future agricultural expansion.

Farmers in the Irangi Hills take every opportunity to enhance agricultural production, as demonstrated by the cultivation on some old conservation structures, a dry lake bottom, and the gradual (though illegal) return of free grazing animals. Thus a continued evolution and improvement in the agricultural use of land may be expected in the Irangi Hills.

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