# Changes within Small-Scale Agriculture. A Case-Study from the Southwestern Tanzania

**Torben Birch-Thomsen & Bjarne Fog**

**Abstract**

*The objective of this paper is through a case study from the southern highlands of Tanzania, to illustrate how the agricultural system has changed within a period from the mid-1950s to the early 1990s in response to both endogenous and exogenous forces. The focus is primarily on the latest response at village level to the liberalization process within the agricultural sector in the early 1990s. New methods, by which remote sensing data from high resolution sensors are used as primary input, are analysed in relation to monitoring and to evaluate rapid land use changes.*

**Keywords**

*Tropical agriculture; land use; intensification; remote sensing; Landsat TM; monitoring; classification.*

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Within the last five decades most agricultural systems within Sub-Saharan Africa have experienced major changes. These changes are typically related to an intensification in terms of increased frequency of cultivation (Boserup 1965; Ruthenberg 1980; Pingali et al. 1987). The causes and effects of the intensification are many, and they vary in time and place. Kates et al. (1993) have placed the theories that seek to explain agricultural intensification into two broad categories:

> '... those that relate production to household needs and wants (usually population-driven) under conditions of "subsistence" and those that relate production to demands from the market.'
> (Source: Kates et al. 1993; p. 8)

The former category is a main topic in the works of Chayanov (1966) and Boserup (1965, 1981) the latter in a large number of broader economic and agricultural models, which have been merged into a theory of "induced innovation" (see Hayami and Ruttan 1985). In order to be consistent with the argument by Kates et al. (op.cit.), that the performance of most African farmers is predictable on the basis of a composite of the consumption and commodity rationales (Turner and Brush 1987), the intensification has to be seen as induced to the farmers by both endogenous and exogenous forces (Birch-Thomsen 1993).

The impetus/speed by which changes will occur, and their effect on the resource management at a given location, may vary according to the nature of the influencing forces. Autonomous intensification may occur when changes in cropping patterns evolve, over a longer period of time in response to increasing population pressure through experimentation, adaptation and assimilation of new techniques to the indigenous traditional knowledge system (Swift 1979). On the other hand, changes may occur more or less 'over night' as a result of, or in response to, changed national policies - which in some cases could be characterized as 'policy-led intensification'.

Consequently, no agricultural system has remained static; rather, they have constantly evolved to meet the needs and constraints induced by endogenous or exogenous forces. With an increasing market integration, though, there is a tendency that changes originating from exogenous forces (e.g. price policies) occur more frequently.

In Figure 1 a somewhat simplified scenario for changes within Sub-Saharan agricultural systems is given, with its possible implications for resource management listed in the boxes.

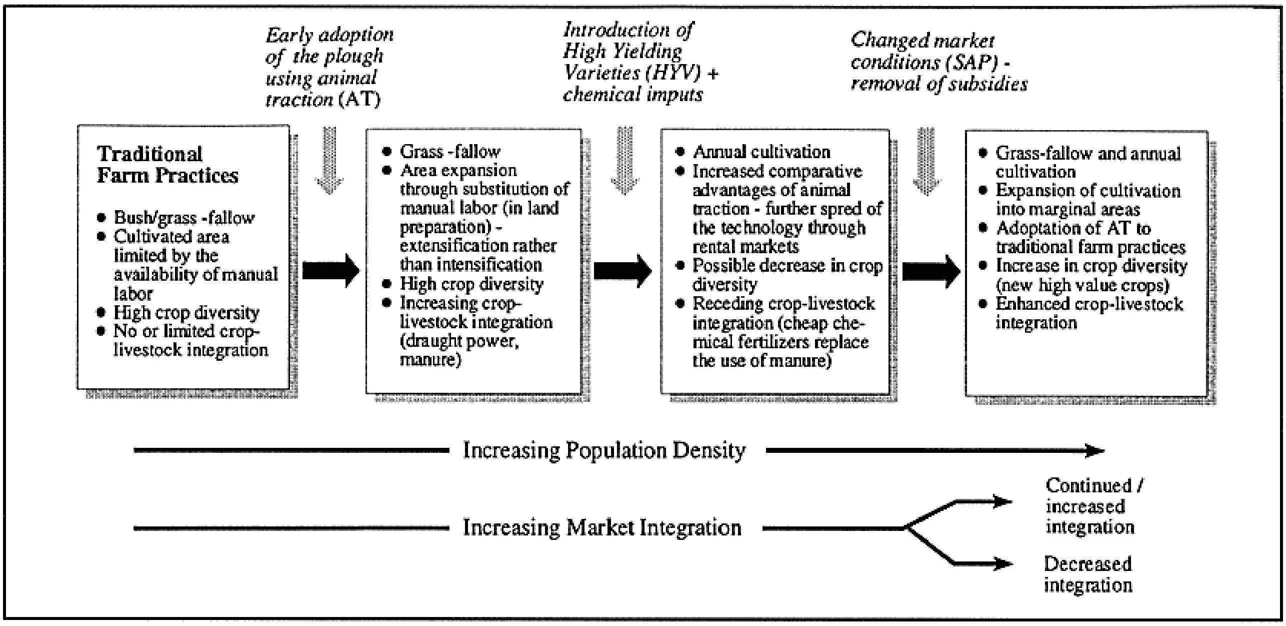



*Figure 1: A scenario of change within agricultural systems in Sub-Saharan Africa, where the adoption of animal traction has taken place. The impetus by which changes occurred at the early stage was governed by the capability of the traditional system to both adopt and adapt new technologies or practices in response to changed needs and possibilities. This indicates a variation in response from one location to another depending on eg availability of land or labour, and all the options given in each box may not materialize. Source: T. Birch-Thomsen (1995, p.2).*

The objective of this paper is two-fold. The first objective is, through a case study from the southern-highlands of Tanzania, to illustrate how the agricultural system has changed within a period from the mid-1950s to the early 1990s in response to different forces - both internal and external. A special effort, though, will be made to capture and evaluate the latest response at village level to the liberalization process within the agricultural sector in the early 1990s, and their implications for the future.

In order to make possible such an evaluation - of the effects of rapid changes in land use practice and resource management caused by changed policies - it is necessary to develop new methods. The second objective is, therefore, to discuss the applicability of methods for which remote sensing data from high resolution sensors is used as input.

## Methodological Considerations

One way of observing the consequences of changed policies on agricultural systems and their resource management is through village studies, including farmer/group interviews and field observations (Casley and Kumar 1988). This method may be expensive, time consuming if carried out on a large scale and often neglects the spatial extension of land use changes. A possible method of obtaining spatial information could be the use of transects to describe land use along predefined lines across the village territory. The Integrated Transect Method (ITM) described by Andriesse et al (1994) is an example of such. It includes a bio-physical characterisation and a description of crop types, cultivation intensity etc. for given transects of land. This method may provide a lot of detailed information on the fields in the transect, but still the spatial extension of the land use pattern is missing.

The spatial dimension of changes prior to 1990 has mainly been documented through analysis of aerial photos taken in 1955 and 1977 (Birch-Thomsen 1993). With the latest development within satellite remote sensing (higher spatial and time resolution combined with lower cost), this could be a method/tool to monitor rapid changing land use systems in the tropics. In order to derive information about land use from a satellite image, classification of the various fields and the surrounding bushland or woods is necessary. Classification only makes sense if the area analysed can be considered to be composed of a limited number of land cover classes, where each pixel of the satellite image can be assigned to a specific class. Much effort has been invested in developing classification methods/algorithms suited to the allocating of pixels in Landsat and SPOT images to land cover classes in intensively cultivated areas in Europe and USA, because each pixel in these areas is likely to belong to one of a limited number of classes. (Kjeld Rasmussen, 1992).

In general, monitoring land use changes in tropical agricultural systems by the use of satellite images is a very difficult task. The individual fields are small compared to the spatial resolution of the images and the plant/crop cover of the fields are often rather heterogenous, because of the common practice of inter-cropping or simply the number of weeds in the fields. In some cases it might even be difficult to separate the fields from the surrounding "bush".

In spite of the problems encountered when using satellite images for studies of changes in tropical land use systems, it is found that analysis of satellite images can provide the spatial information about changes revealed in other inventories, such as household interviews, missing the spatial dimension. The method is to capture changing features in the satellite images that can be an indicator of a more general change of land use, in this study the newly ploughed bare fields.

Two classification methods have been tested in this context, a simple Parallelepiped or Box classification and calculation of a band ratio known as Normalised Difference Vegetation Index (NDVI).

With the Box classification method a pixel is assigned to a class according to the parallelepiped decision rule, where the actual pixel value is compared to upper and lower class limits in one or more image bands. This method is often used as a first-pass and an explorative classification, where the upper and lower limits for a class can be changed interactively during the process of classification.

The other way to classify images is to use band ratios. A common band ratio is the NDVI-index calculated by dividing the near infrared reflectance by the red reflectance (Tucker 1979), which gives high values for healthy green vegetation and low values for bare areas.

Based on the above considerations the methodology of the present case study will be to combine data from field observations and farmer/group interviews, collected in 1990/91 and 1993, with data from satellites in order to capture rapid changes in land use.

## Data

Extensive field data - including a village questionnaire (31 households); group-meetings; field location, measurements and history of selected farms; land use along transects within different land facets - were collected in 1990-91 (Birch-Thomsen 1993). In 1993 interviews were conducted with groups of 10 to 15 farmers about the general changes within farming since 1989/90, and as a supplement three farmers were re-interviewed in-depth. Fields at different stages of the cropping cycle were identified and located on both maps and hard copies of the satellite image from 1991.

The remote sensing data available for this study was Landsat TM data channels 3, 4, 5: one sub-scene from 1991, two from 1992 and one from 1993. A Landsat image has a spatial resolution of 30 by 30 metres and the channels 3, 4, 5 cover the electromagnetic spectrum from 0.5 to 0.9 um, which means that the first two are in the visible and the last in the near-infrared part of the spectrum. The satellite images from 1992 were recorded in May just at the end of the rain season and during the dry season in August. The images from 1991 and 1993 were both recorded within the dry season - July and August.

Before the images could be used in a comparison, the images were co-registered with the image from May 1992 as the master image (the image from May 1992 had been registered to the UTM coordinate system of maps in Tanzania).

## The Study Area

Ulinji Village is located on the Fipa Plateau in Sumbawanga District, Rukwa Region, in the south-western part of Tanzania, approximately 15 km southeast of the district and regional centre, Sumbawanga. According to an agro-ecological zoning of Rukwa Region by King et al. (1979) the study area falls into two zones: The Namanyere-Laela Plain (1900 m a.s.l.) towards the west and the Yamba-Mbizi Range (2100 m a.s.l.) towards the east (Figure 2). The two zones are separated by a moderate to steeply sloping escarpment following the general physiographical gradient of the area in a NW-SE direction. The mean annual rainfall is between 803-960 mm and the natural vegetation is dominated by grassland with scattered trees and bushes.

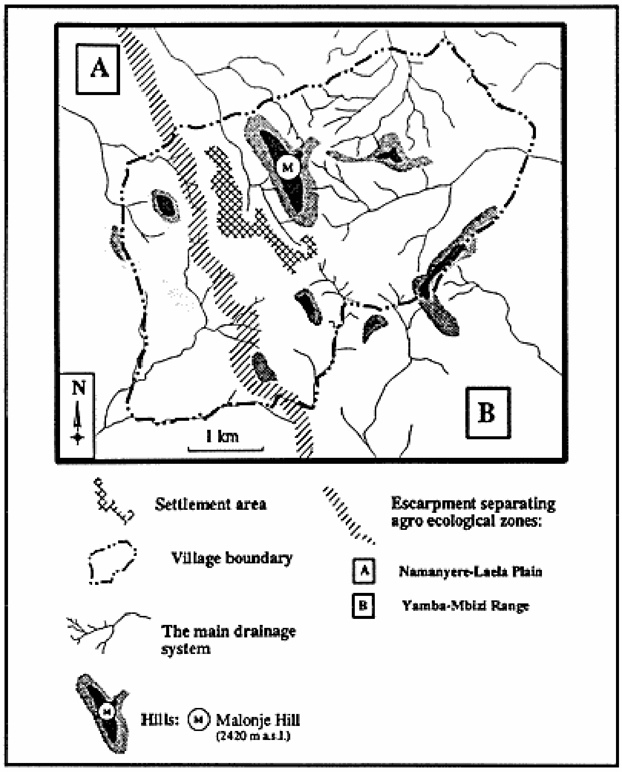



*Figure 2: The study village Ulinji, Rukwa Region, Tanzania.*

## Changes in Agriculture prior to 1990

During the last 40 years the agricultural system of the study area has faced major changes induced both by exogenous and endogenous forces. With reference to Figure 3 a brief description of the transformation, its major causes and the effects on land use pattern, will be given in a historical context.

In the late 1950s and early 60s the prevailing form of agriculture was a mound system, traditional for the Fipa of southern Tanzania and the Aisa Mambwe of northern Zambia (Willis 1966; Strømgaard 1988), where grass turves are thrown into circular mounds (kufundika). Mounds are made at the end of the rains and left throughout the following dry season in order to let the grass decompose. This system is based on a rotation of the traditional crops finger millet, beans and cassava, with the latter as a perennial mixed intercrop. According to interviews with older farmers and data from previous studies (King et al. 1979; Collinson et al. 1980) farmers practised a cultivation cycle of approximately 13 years, three years of cultivation followed by ten years of fallow. Due to the lack of population data earlier than 1978, the population figure in the late 1950s and early 60s has been estimated to be around 100 based on village interviews and early written material on the Fipas (Willis 1966). With the exception of a small village located on the edge of the escarpment close to a stream, the settlements were scattered. Based on the

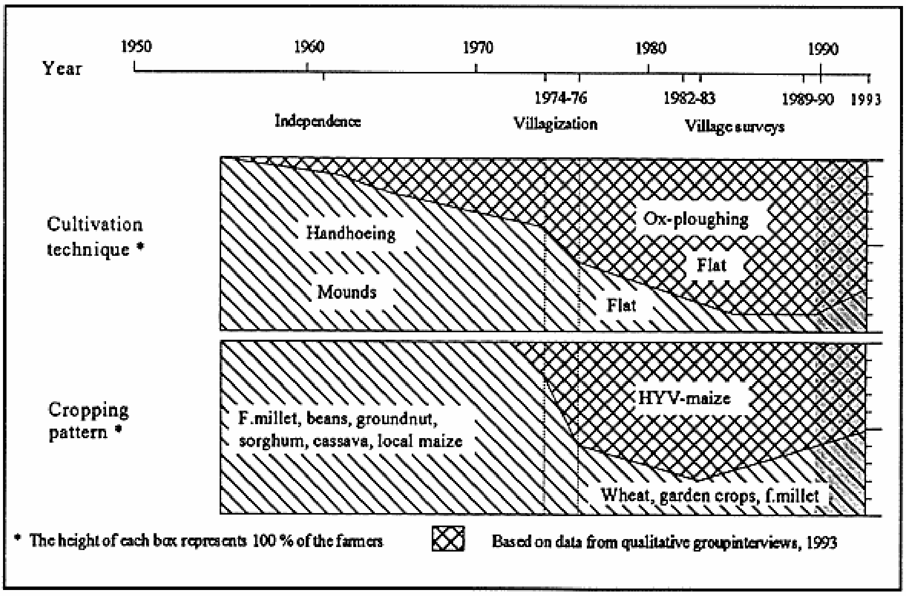



*Figure 3: Changes within agriculture in Ulinji Village.*

village area identified in 1990 (28 $km^2$), the population density in the early 1960s can be estimated to approx. 4 pers/$km^2$. As reflected by the low man/land ratio a large part of the village area was virgin land, and the eastern part of the plateau was only used for grazing (Birch-Thomsen 1993).

At this stage an early adoption of animal traction took place. A few farmers, returning from migrant work, brought ploughs and the knowledge of how to train oxen for traction to the village. Given a low man/land ratio the substitution of manual labour with animals enabled farmers adopting this new technology to expand their land under cultivation. By the mid-1970s approximately 40% of the farmers used animal traction in primary tillage but with little or no change in cropping pattern.

Between 1974-76 a major change in land use occurred as a consequence of the national resettlement programme. People in the study area were moved into a dense village on the plateau close to the road. The change towards a more intensive land use pattern, caused by villagization, was enhanced through the National Maize Project started in 1974-75 which involved an introduction of subsidized hybrid maize seeds, fertilizers and pesticides (hybrid seeds are produced by crossing genetically dissimilar plants. The yield potential is superior to that of the parent lines, but cannot be maintained in succeeding generations (Reijntjes et al. 1992)). These inputs made permanent cultivation with high outputs possible, and reduced the importance of the previous traditional practice of fallow.

Furnished with the heavily subsidized input prices and the pan-territorial pricing system, production of especially maize for the national market became economically feasible even in such a remote region as Rukwa (Raikes 1988, p. 58). As a result, market integration increased rapidly during the 1980s, and by the time of the village survey (1990) 84% of the farmers were selling crops - nearly 40% of the total village production of maize was sold through the official marketing channels.

Although problems with the reliability of population figures obtained, due to a discrepancy between village and district records, the population density in the study area is estimated to have increased from 25 pers/$km^2$ in 1978 (national population census) to nearly 47 in 1990 (Birch-Thomsen 1993). During the 1980s both high population growth and increased intensity of cultivation on the plateau close to the settlement area forced farmers to look for new areas for cultivation. Land previously of marginal interest was increasingly put under cultivation - especially on the moderately sloping parts of the escarpment. By 1990 a few plots, covering approximately 0.5 $km^2$, had been opened for cultivation on the north-eastern plateau previously reserved for grazing.

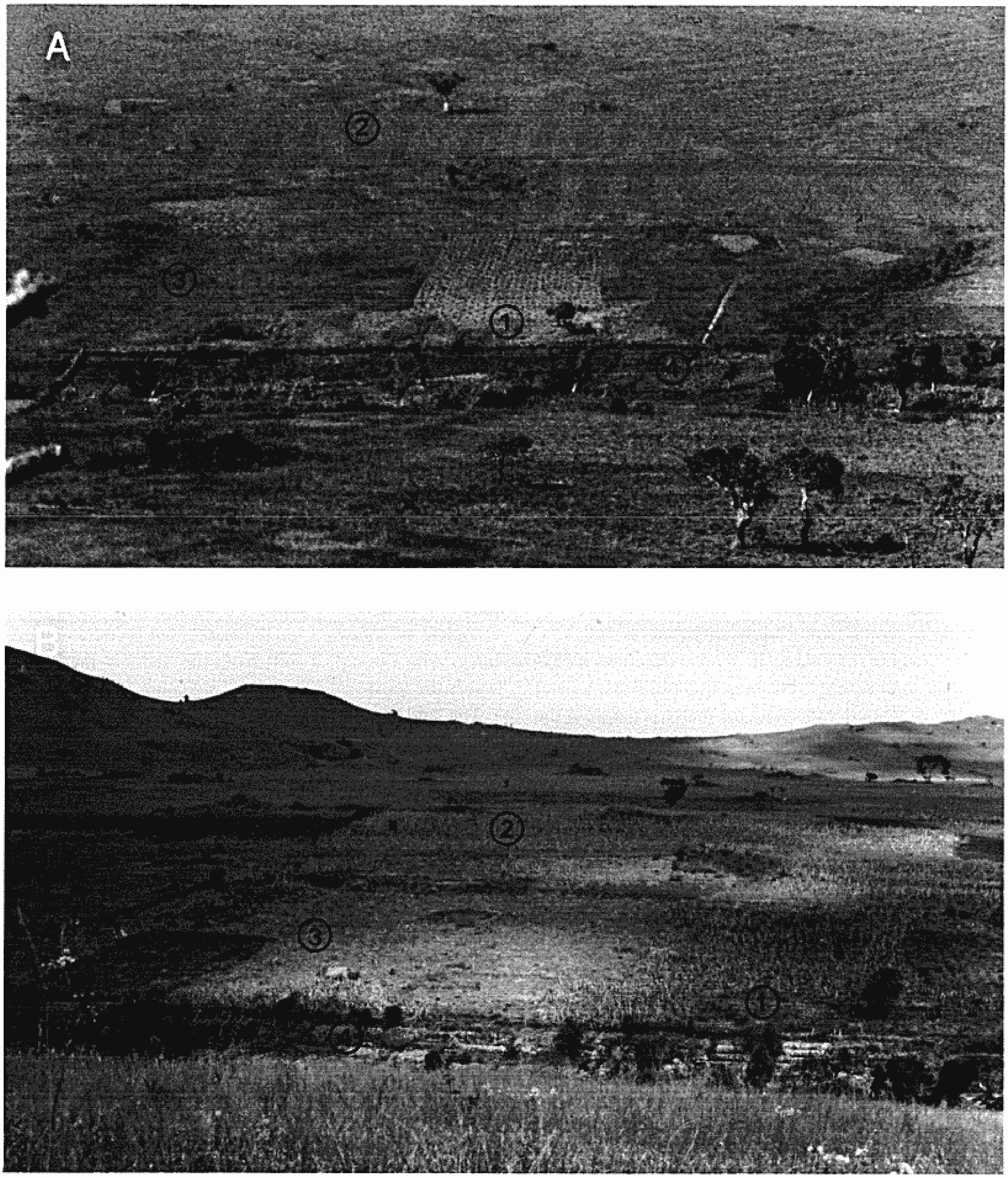
Along with the land use intensification, additional changes in cultivation techniques took place. The use of animal traction for ploughing was rapidly adopted, both in terms of farmers ownership of ploughs and trained oxen and also induced by the emerging rental market (used by 26% of the farmers). By the crop season 1989/90 86% of the cultivated upland fields were ploughed using animal traction.

To sum up the changes up to 1990, it is evident that the resettlement of people, the increase in population and thereby the need for expansion of land under cultivation, and the success of hybrid maize together with a change in cultivation techniques - adoption of animal traction for ploughing - accounts for the major changes in the agricultural system within the study area. Changes prior to the resettlement scheme in the mid-1970s were mainly induced by endogenous forces, but subsequently changes were increasingly influenced by exogenous forces.

## Expansion of Land under Cultivation in the 1990s

During fieldwork in July 1993 major changes in land use were observed within the village. Firstly, cultivation had expanded into an area not previously identified as part of the village area - towards the north and northeast beyond the hills. The village boundary shown in Figure 2 therefore represents the new area (approx. 32 $km^2$) used and perceived as the land available to villagers of Ulinji. In addition to a further expansion of the area under cultivation in the north-eastern plateau - compared to that already observed in 1991 (Birch-Thomsen 1993) - a number of fields newly opened for cultivation were observed. Virgin grassland had been tilled at the end of the rainy season (April-May) in preparation for cultivation in November/December. The previously common technique of making mounds was observed, but most of the new fields were ploughed using animal traction - an adoption of the 'new' and labour saving technology into the traditional practice of farming widely used prior to the villagization process.

Secondly, an increased number of fields in fallow on the south-western plateau was observed. During a group meet-




***Picture A+B:** The pictures illustrate the expansion of cultivation in the NE-plateau of the study area. A) Taken in June 1991 of newly tilled fields: (1) mounded field; (2) ox-ploughed field; (3) grassland; (4) stream. B) Taken in July 1993 at the same location as in A: (1)+(2) maize cultivation on the previously mounded and ox-ploughed fields; (3) harvested field with temporary hut; (4) intensive gardening on the fluvial deposits along stream; (5) newly tilled field.*

ing it was explained that some farmers had shifted their cultivation to the NE-plateau and left the fields close to their homesteads in fallow. These fallow fields were either used for grazing or planted with eucalyptus trees - the availability of firewood and building poles had decreased dramatically.

Thirdly, there had been a change in the cropping pattern within the village. Wheat had been introduced as a new cash crop at the expense of maize, though the latter continues to be an important staple food crop. In addition farmers stated that the acreage cultivated with beans, sunflower and finger millet had increased. In the case of finger millet this is especially true on the newly opened fields.

Fourthly, garden cultivation along small streams and depressions had been further expanded, especially on the NE-plateau.

To illustrate the transformation mentioned above, data on acreage and crop pattern for three selected households in the crop seasons 1989/90 and 1992/93 is given in Figure 4. The households represents three different categories of farm practices within the village in terms of size of holding, availability of implements and cash income, and they are taken to be representative of the different farming strategies found within the village. In general they have all expanded their total acreage, but in household B the upland acreage has decreased, especially the maize acreage, at the expense of an increased garden acreage. Maize is produced for subsistence whereas garden products are to provide the household with cash income. A similar change in the maize acreage is shown in household C, but in this case

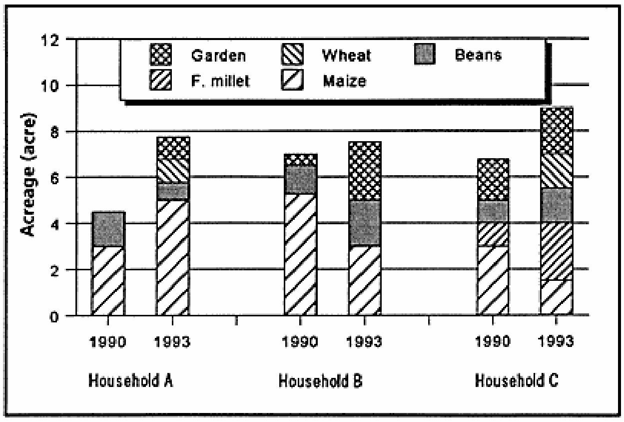



*Figure 4: Changed cropping pattern in the three selected households, Ulinji Village 1990-93.*

maize as a cash crop is substituted by the new crop wheat. The expansion of the acreage in finger millet is a result of new land brought under cultivation in the NE-plateau. Household A, though, consist of one of the few farmers actually increasing their acreage of maize, and in addition wheat has been introduced. The wheat crop was cultivated on one of the old maize fields close to the settlement, whereas maize to some extent was shifted to the new and more fertile location on the NE-plateau. The main reason for this shift was lack of or too expensive fertilizers. Household A is therefore an example of a household trying to continue or increase its involvement in the market through the expansion of its acreage into new and more fertile parts of the village area with minor changes in the cropping pattern. Likewise, household B continues its involvement in the market but through a shift in cash crops and by increasing the cultivation of the fluvial deposits along streams - gardening. Finally, household C represents farmers who withdraw from maize marketing, and returned to the traditional cropping cycle with finger millet as the dominating crop during the first years. As a substitute to maize marketing, wheat has been introduced with the purpose of selling to private dealers. The result is not a complete withdrawal from the market but rather a reduced integration through a shift from the national market towards the local.

The land use changes within the 1990s, observed during fieldwork in 1990/91 and 1993, are mainly caused by exogenous factors related to the national policies launched in the mid-1980s. The period of structural adjustment was started by the agreement between the Tanzanian government and the World Bank on the Economic Recovery Programme (ERP) 1986-89 (Havnevik 1993). But it was not until the implementation of the Economic and Social Action Programme (1990-93) that the liberalization within agriculture really took off. The pan-territorial pricing system was removed, a general abolition of subsidies and a legalization of the negotiation of prices between private dealers and farmers are some of the main changes affecting farmers, especially in a remote region such as Rukwa. As shown above, farmers have reacted rapidly to these policy induced changes, which have had an immense impact on land use and resource management in locations like Ulinji Village.

The consequences of changed policies on agricultural systems and farmers resource management has been analysed above through village surveys including farmer/group interviews and field observations. In the final part of this paper we will elaborate on the applicability of satellite remote sensing as a method and tool for rapid identification of indicators which can sustain and add spatial dimensions to the data obtained from the village survey.

## Applicability of Satellite Remote Sensing

From the historic analysis of the agricultural changes and their implications on the land use pattern in the study area, it is clear that the transformation does not simply follow a linear development. During the early stage of transformation, prior to the villagization, changes were mainly induced by endogenous forces - the autonomous intensification. On the other hand, with the increased influence of state policies and market integration changes tend to occur far more rapidly. The case of the forced resettlement of people is a perfect example of a policy-led intensification, causing dramatic changes over a short period of time. Another example is the rapid response by farmers to the changed marketing conditions as a result of the structural adjustment programmes (see also Figure 1). The data obtained through interviews combined with field observations in 1993 were able to capture the general changes which occurred in the early 1990s, but did not provide detailed information on the spatial extension.

The first visual interpretation and analysis of the spectral signature in the different bands of the images showed that a general classification of the entire village area was impossible. But it also showed that several small areas mainly east of the village were rather easy to distinguish from the surroundings. According to the village survey in 91 and 93, these areas were new bare fields, mainly ox-ploughed, which have been added to the cultivated area during the last year. The fields are without vegetation or only very sparsely vegetated from the ploughing in May to the end of harvest in July/August.

Analysis of all the Landsat images show that a newly ploughed field has a low reflectance in the near infrared band especially in the rainy season probably because of the missing plant cover combined with the darkness of the tilled surface soil. In the images from the dry season the same fields are still to be recognized, but not as clearly as in the image from the rainy season. Analysis of the two images from 1992, from the rainy and dry season, show

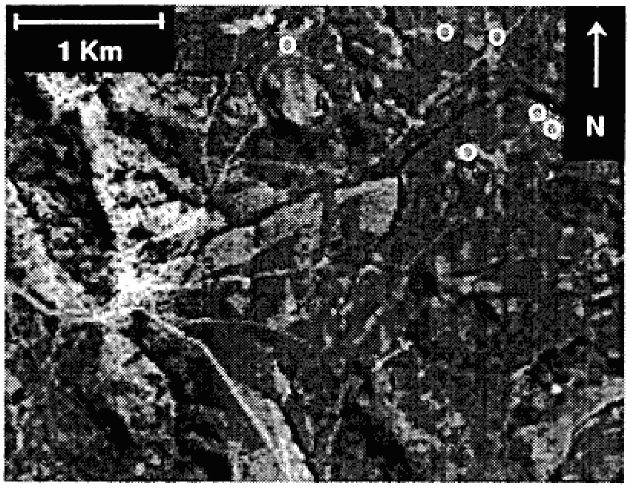



***Figure 5:*** *Landsat TM channel 3, 4 and 5 showing the village territory of Ulinji, contrast stretched to set off the newly ploughed fields. (As indicated on the image).*

that a box classification or NDVI calculation followed by a visual interpretation can be used to establish a general view of the spatial distribution of new fields brought under plough (see Figure 5). It should be stressed that the class intervals used in the supervised classification are not necessarily meaningful for other villages in the same image, because of the variation in soil type, landscape and vegetation cover from one region/village area to another.

Analysis of the satellite images also show that the time for the recording is an important factor when using satellite images to discover/monitor change of land use at village level.

The accuracy of the classification can in this work not be calculated as a percentage of correct classified pixels, because the exact limits of the fields are not available, only the location of the fields identified during fieldwork in 1991 and 1993. This restricts the control of accuracy, to the calculation of the number of fields classified correctly. In the images from 1993 the classification hits all the fields (12) identified during fieldwork and this may be an indicator for the accuracy of the classification.

Due to the relatively small size of the newly ploughed fields a large number of pixels classified as such are mixed pixels covering both bush-/grassland and fields. The calculation of the exact acreage of fields brought under plough per year makes therefore no sense, although counting the number of new ploughed fields per year, may give an idea about the extension of this agricultural practise, and thereby documents tendencies revealed during interviews and field observations within the land use practise.

The spatial distribution of new fields prepared for cultivation - winter-ploughed - during the years 1991 to 1993 are shown in Figure 6. (Shown as overlays on top of channel 5, aug. 1992). It reveals a rather massive expansion of cultivation in the NE-plateau of the village area during 1991 and 1992 followed by a decreasing number of new plough fields added in 1993. This picture is consistent with the results from the farmer interviews, and prove that changes induced by exogenous forces may cause a very visible change of land use at village level almost "over night" - the agricultural systems are far from static.

## Perspectives

The present case study is believed to represent a scenario of change generally found in many parts of Sub-Saharan Africa.

Given the speed by which changes seem to have occurred within the last decade or so, there is a strong need for the development of methods to assess the consequences of these changes on the management of the natural resources. This is especially relevant to local, regional and national administrators/planners within the agricultural sector of most Sub-Saharan countries, in order to enable the implementation of both ecological and socioeconomic sound initiatives/policies for the future. The present study shows both the potentials and problems in using satellite remote sensing data (Landsat TM) for monitoring land use changes at village level. With recent developments within the field of remote sensing towards higher spatial and time resolution the possibilities to capture the spatial heterogeneity, within tropical farming systems are growing.

## Acknowledgement

Collection of field data and procurement of satellite images have been possible through the involvement in the joint project 'Agricultural and ecological consequences of deforestation and afforestation in Tanzania and Zambia based on satellite remote sensing' between Institute of Geography (University of Copenhagen), Institute of Resource Assessment (University of Dar es Salaam) and Department of Botany and Department of Geography (University of

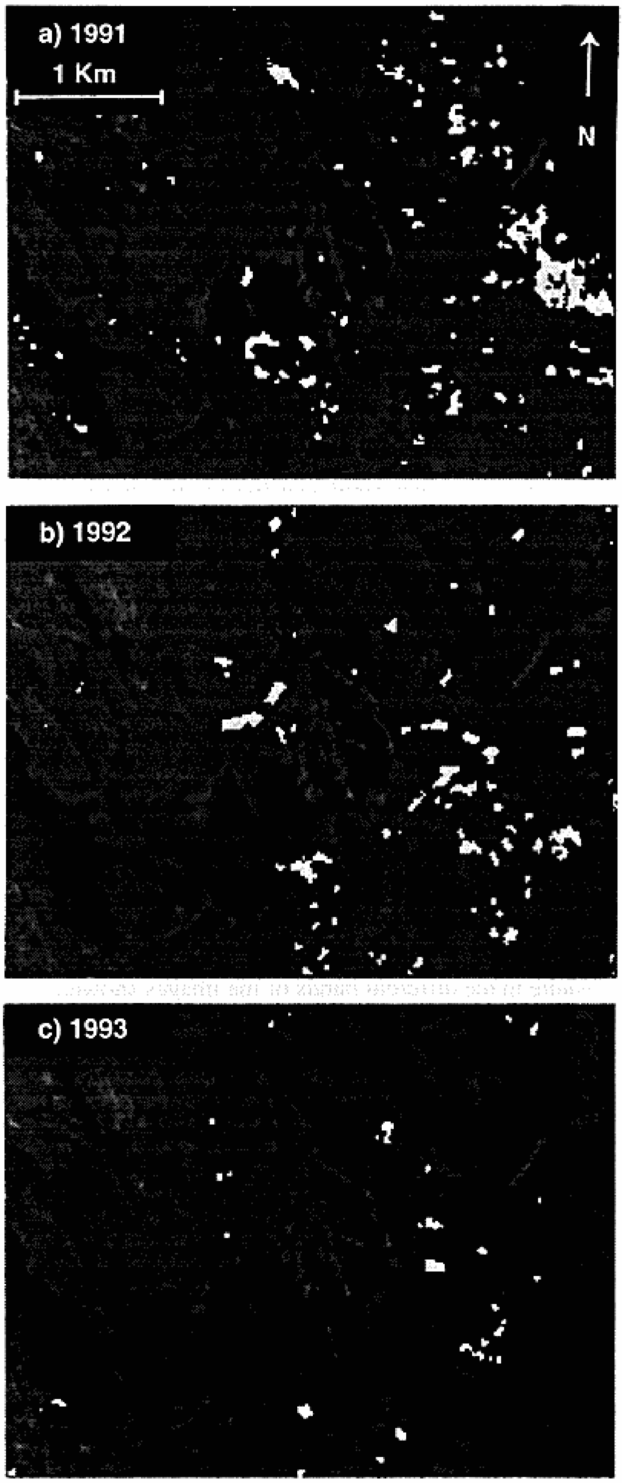



*Figure 6: Spatial distribution of newly ploughed fields belonging to Ulinji Village in a) 1991, b) 1992 and c) 1993 classified by the use of box classification and visual interpretation.*

Zambia). The project has been funded by DANIDA under the Programme for Enhancement of Research Capacity in Developing Countries (ENRECA).

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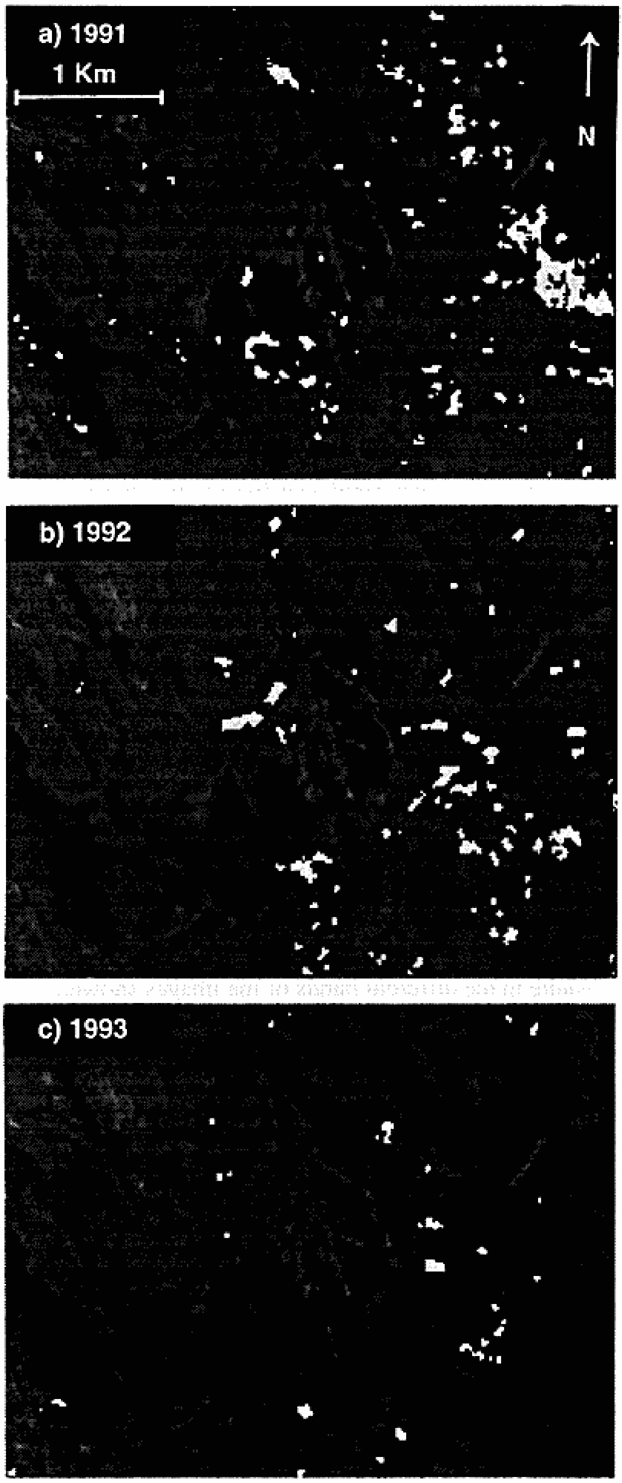


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The present case study is believed to represent a scenario of change generally found in many parts of Sub-Saharan Africa.

Given the speed by which changes seem to have occurred within the last decade or so, there is a strong need for the development of methods to assess the consequences of these changes on the management of the natural resources. This is especially relevant to local, regional and national administrators/planners within the agricultural sector of most Sub-Saharan countries, in order to enable the implementation of both ecological and socioeconomic sound initiatives/policies for the future. The present study shows both the potentials and problems in using satellite remote sensing data (Landsat TM) for monitoring land use changes at village level. With recent developments within the field of remote sensing towards higher spatial and time resolution the possibilities to capture the spatial heterogeneity, within tropical farming systems are growing.

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