

**ASSESSMENT OF THE LAND USE CHANGES DUE TO TRADITIONAL
IRRIGATION ACTIVITIES: THE CASE STUDY OF FOUR VILLAGES
AROUND RUAHA MBUYUNI, IRINGA AND MOROGORO TANZANIA.**

BY

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**A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE
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ABSTRACT

The study on assessment of land use changes due to traditional irrigation activities was conducted in four villages around Ruaha Mbuyuni from June 2000 to June 2001. Three sets of aerial photographs (1955, 1976 and 1999) were used, interpreted on mirror stereoscope and analysed using GIS-ARC/INFO program. The area of each class was calculated for each data set from which the rate of expansion of irrigated farms was determined. The questionnaire survey was conducted to collect information on the historical changes in natural resources and socio-economic activities responsible for land use changes and analysed using SPSS program. Stratified random sampling was also conducted for soil physical and chemical analyses. By using rating procedures the contribution of soil properties in land use changes was carried out. The results showed that irrigated fields expanded by 2056.8ha and 1528.6ha with expansion rate of 97.94ha/yr and 66.46ha/yr from 1955 to 1976 and 1976 to 1999 respectively. Human population increased from 2886 to 16877people between 1967 and 1998. Irrigation activities have been observed to increase the extent of socio-economic activities like firewood gathering and building. The results for soil analysis indicated that, total nitrogen, available phosphorus and organic matter content was low in all fields and therefore low soil fertility in the area. Exchangeable Na were observed to be high in some fields and having high potential to cause soil salinity and sodicity. Other chemical properties i.e pH values, Ca, Mg and CEC were observed to be within the acceptable range for irrigation activities and crop productivity. The soil physical properties indicated that the bulk density of the soil were within the acceptable range for water

infiltration and plant roots penetration. The soil textural class was observed to range from sand loam to sand clay loam for the topsoil and sand to clay for the subsoil. Generally, the results have shown that the pattern of land use changes in the study area were due to irrigation activities taking place in the area which has influenced population growth and socio-economic development.

DECLARATION

I, **ELIZABETH RUGENGA** do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has not been submitted for a Degree award in any other University.

Signature: 

Date: 15th. July. 2002.

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DEDICATION

To Lorivi, Kelvin and Kennedy.

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CHAPTER ONE

1.0 INTRODUCTION:

1.1 The role of irrigation

The agricultural sector forms the basis of Tanzania's economy. The sector is estimated to employ 80% of the economically active population of the country. However, soil and climatic conditions and the use of the land beyond its limit result in decreased agricultural production (FAO, 1992). The development of agriculture, especially irrigated agriculture should therefore be approached cautiously since it is a natural resource dependant industry. Its survival can only be assured if the natural resource base on which it is heavily dependent is sustained. The knowledge of the type, location and quality of resources and how these are utilised is a pre-requisite to successful resource development and conservation. It is therefore imperative to have inventories of the past, present and future land resource utilization of an area. In this regard, both the resource and activity must be monitored if they are to be maintained in a productive state in a sustained basis (Van Riet Cooks, 1988).

According to Vaughn, *et al.*, (1979), irrigation can be defined as the artificial method of applying water for supplementing rainfall, to improve crop yield and quality in areas where rainfall is insufficient or ill-timed. Irrigation also increases the extent of cultivated areas and increases the harvest frequencies to two or more per year. Various types of irrigation methods can be used depending on the local conditions, cost, crop types, and the type of water resources that are being utilised. Rivers, dams, reservoirs and groundwater sources are relevant both for large and small-scale irrigation systems (NORAD, 1994).

1.2 Land use

Land use is any kind of permanent or cyclic human intervention to satisfy human needs, either material or spiritual or both, from the complex of natural and artificial resources which together are called land. It refers to man's utilitarian activities on the land (Khanna and Kondawar, 1991). Land is the most important natural resource, which embodies soil, water and associated flora and fauna involving the total ecosystem. Land as a natural resource is there to be used, and uses takes place in specific areas at specific localities. Of late growing population and human activities are increasing the pressure on the limited land and soil resources for food, energy and several other needs.

An assessment of the land available in the world for productive uses reveals an alarming decreasing trend in the per capita availability of arable land from 1.2ha in 1951 to 0.48ha in 1981, and by 2000 AD it was estimated to decline further to 0.15ha (Rao, et al., 1991). Comprehensive information on the spatial distribution of land use/land cover categories and the pattern of their change is a prerequisite for planning, utilisation and management of the land resources of the country. Land use/land cover inventories are assuming increasing importance in various resources sectors like agricultural planning, settlement and cadastral surveys, environmental studies and operational planning based on agro-climatic zones. Information on land use/land cover permits a better understanding of the land utilisation aspects on cropping patterns, fallow lands, forests, grazing lands, wastelands and surface water bodies, which is vital for developmental planning (Vink, 63).

1.3 Irrigation and land use changes

Rural land use and the pattern of uses change in response to population growth, socio-economic developments and improved farming practices and technology in the area. In the process, irrigation projects transform the land into two ways. First by direct modifications of the land surface that occur when canal networks are constructed and land is cleared, shaped and leveled for irrigation. Second by indirect in-depth transformations that take place when the water and salt balances in the region are changed following the import of additional quantities of water and salt into the area. Irrigation can also change the land use by increasing productivity hence more farming activities or can lead to abandoning of some farms due to improper management of irrigation activities (Shanan, 1987).

1.4. Land potential

The ability of land to be used for sustained agricultural production is finite. Soil type, climate, relief, hydrology, pests and diseases set limits to agricultural production. FAO (1992) estimated that about 1500 million ha of the earth's land surface is suitable for agriculture. Irrespective of these figures, the world's arable land resources are finite and are coming under increasing pressure from growing world population and land degradation (Douglas, 1994).

1.5. Irrigation research in Tanzania

According to a study by FAO (1981), Tanzania has enough land to produce food for her present and future population. Land with good agricultural potential in Tanzania is estimated at 10 million ha (FAO 1992). However, the precarious food situation

experienced in the country indicates that the mere availability of land is not enough to attain self-sufficiency in food production. This is probably because in the past almost all agricultural research, and especially irrigation research, carried out in Tanzania has been largely confined to observation trials and has therefore failed to provide answers to the most pressing problems facing irrigation in the country (FAO, 1972).

The four villages around Ruaha Mbuyuni use surface traditional irrigation methods for food crops mainly onions, paddy and maize. Traditional irrigation refers to an improved indigenous irrigation initiated locally by farmers. It consists of the application of water on soil surface without taking account of soil moisture depletion and therefore no proper management of irrigation and drainage network (Hiller, 1979). Due to the low rainfall in this area, agricultural activities entirely depend on irrigation throughout the year (TIP, 1992).

According to a research conducted by Wansink (1992) on Inventory Study of Mbuyuni area, it was observed that the population of the area has been increasing every year due to irrigation activities. It was also observed that some of the watershed areas were facing deforestation and hence causing serious sedimentation to the lowlands and crop yield reduction. The study indicated that agricultural land, especially the irrigated one, was deteriorating due to fertilizers and other chemical applications therefore resulting in some farms being abandoned. Despite all these, no research work has been done in Ruaha Mbuyuni, to investigate the extent to which land use has been changed due to irrigation and related activities. It is against this

background that this research is initiated to investigate and assess the extent of land use changes due to irrigation development in the four villages around Ruaha Mbuyuni.

This study is aimed at assessing the effects of traditional irrigation activities on land use changes. The study is intended to create awareness of detrimental effects of irrigation on land use to those who are concerned and formulate strategies to resolve the problems caused by irrigation in order to enhance sustainable use of land resources.

1.6. Objectives:

The main objective of the study was to assess the effects of traditional irrigation activities on land use changes in four villages around Ruaha Mbuyuni.

The specific objectives were:

- (a) To assess the rate of expansion of irrigation farms and its effects on land use changes;
- (b) To carryout field verification of the study area and to assess the socio-economic activities contributing to land use changes;
- (c) To assess the soil physical and chemical status in the cultivated areas, which may cause land use changes;

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. The present and future extent of irrigation

The area of land irrigated in the world today is close to 250 million hectares, of which about two-thirds is situated in five countries –China, India, Pakistan, the Soviet Union and the USA (Shanan, 1987). With world populations growing concurrently with expectations of higher standards of living, world food and fibre demands will increase. Since arid lands become highly productive with the introduction of irrigation water, and the production of rain-fed areas increases considerably with supplementary irrigation, the improvement of existing irrigation projects and the opening up of new irrigated areas will continue to make significant contributions to solving the world's expanding food and fibre needs. In order to ensure the stability and permanency of these projects the potential hazards intrinsic to irrigation development cannot be overlooked, and the land transformations that may take place should be taken into consideration (Shanan, 1987).

2.2. Land use changes assessment

Land use changes assessment seeks the relevant information on the physical properties and status of an area as well as how the land is used over different years and its socio-cultural impacts, both physically and economically (Larsson, 1988). Land use changes assessment plays an important role in planning the use and conservation of land resources for the present and future generation. The utilisation of land resources in many irrigation schemes in the developing countries is not optimum and much can be gained by a proper utilisation of these resources to reduce

land use changes which are associated with land resource degradation (Brown and Nooter, 1992).

2.3. The role of remote sensing in studying land use changes.

Remote sensing is the acquisition of data concerning objects or features on the earth's surfaces or in the atmosphere through the use of imaging devices (sensors) located at positions remote from the subjects of investigation (Avery and Berlin, 1985). The sensors record electromagnetic radiation (EMR) that is reflected or emitted from these objects or features. Remote sensing includes the collection of data, their display, their analysis or interpretation and their subsequent use for purposes of inventory, survey, monitoring, planning and management (Cochrane, 1986).

Land use can be readily seen on air photographs and satellite images, including such aspects as the proportions of arable and maintained pasture, forest plantations, orchards, the pattern of the fields and the extent of urban or village use of land (Dent and Young, 1981). Maps showing the existing land use have many planning applications, both in developing and developed countries, and air photographs and satellite images with a measure of ground control are eminently suited to this task. Therefore, comparing air photographs and satellite images of different years can assess changes in land use and earlier studies undertaken using remote sensing illustrate the environmental monitoring capability of these techniques.

Land transformations resulting from irrigation development are in all cases spectacular especially when seen from the air or recorded in satellite imagery. Aerial photographs showing the boundaries between a desert and the sown in, for example, the Nile valley in Egypt, the Central Valley in California, or the Rajasthan Canal in India, exhibit dramatic pictures of the contrasting land surfaces and highlight the transformations that have taken place as a result of irrigation making the desert blossom (Shanan, 1987).

Rao (1991), pointed out that remote sensing is being operationally used to predict crop acreage and yield estimate of wheat, rice and sorghum in India. It is being expanded to cover other major crops in the country. Crop acreage and condition assessment for important commercial crops like oil seeds, cotton and mulberry are being provided. It was also pointed out that satellite remote sensing is playing an important role in survey and monitoring of forests. Hay (1974) also reported that conventional, medium scale aerial photographs have been used for decades in some regions for identification of major crops and monitoring of crop area allotments. It was also pointed out that surveys of agricultural land from space altitudes permit the identification of present use of the land and show population settlement patterns and transportation networks. Such survey also permit the identification of land characteristics such as major soil types, drainage and topographical relief patterns as a basis for evaluating the best potential use of the land.

In Rukwa region Tanzania, Mohammed (1985) used remote sensing techniques to carry out a comparative study of changes in agricultural land use in 28 villages of

two contrasting agro-ecological zones within the region. Changes in land use were observed in the plateau area where there is abundant arable land along the shores of Lake Tanganyika. The report further concluded that agricultural land use changes are a function of the physical environment, agricultural system and settlement.

A study of land use/land cover changes and deforestation rates for the rain forests of the Nguru mountains in Morogoro, Tanzania was carried out by Monela and Solberg (1998). The authors used remote sensing techniques, maps and field surveys. The results showed that forest encroachment for subsistence agriculture as well as establishments of settlements by indigenous people are the main causes of rain forest degradation and degradation pressure.

Mbilinyi (2000) used panchromatic aerial photographs (of 1963 and 1978), Landsat TM satellite imagery (of 1995) and GIS to assess land degradation and its consequences in Ismani division, Iringa Region, Tanzania. The change detection analysis showed that a large part of miombo woodland was cleared during the period 1963-1978 due to the resettlement program of the 1970s. The analysis also showed that increase in the coverage of miombo woodland was realized in the period 1978-1995 due to results of woodland conservation efforts by Concern and village committees.

2.4. Methods used for mapping land use.

Indurabudi et al., (1998) used panchromatic aerial photographs and digital data of Landsat Multispectral Scanner (MSS) and Landsat Thematic Mapper (TM) to

analyse land cover changes in the Riam Kanan watershed in Indonesia. Remotely sensed data were analysed using ILWIS software. Colour composites for Landsat MSS and TM data were made. Visual interpretation followed by screen digitizing was applied to obtain digital data. Then the area of each land cover type was calculated for each data set and individual results integrated to determine the rate of change.

Omar et al., (1998), used aerial photographs in studying land degradation of irrigated areas in Kuwait. Aerial photographs at a scale of 1:29000 was used to prepare a mosaic for the Wafra area of Ehiopia at a scale of 1:17000. The photos were of a minimum of about 60% forward and 30% side overlaps. This means that it was possible to use only the central portions of the photos, thereby reducing distortions due to relief and tilt. Printing was done on single-weight papers with 1.7065 time magnification to achieve 1:17000 scale. The grid co-ordinates used on the map were based on the Universal Transvesal Mercator (UTM) grid zone 38, international spheroid with a grid interval of 200m. Hierarchical system was used, devised by the US Geological Survey (USGS), in the classification system for description of land use/cover (Anderson et al., 1976). The USGS system attempts to meet the need for current overview of land use and land cover on a basis that it is uniform in categorisation at the generalized first and second levels. The categories of land use and land cover developed in the USGS classification system can be related to system for classification of land suitability, vulnerability of certain management practices, potential for any particular activity, or land value, either instrinsic or speculative. The functions of current land use are usually associated with certain types of cover, e.g.

forest, agricultural or urban. Thus, the image interpreter attempts to identify land cover patterns and shapes as a means of delivering information about land use.

2.5. Land resources, which influences land use

According to FAO (1995), "*land*" is a delineable area of the earth's surface, encompassing all attributes of the biosphere immediately above or below this surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes and swamps), the near-surface sedimentary layers and associated ground water reserves, the plant and animal populations, the human settlement pattern and physical results of past and present human activities (terracing, water storage or drainage structures, roads and buildings). The components of the natural land unit can be termed land resources, including physical, biotic, environmental, infrastructural, social and economic components, in as much as they are fixed to the land unit. Land resources include all those features of the land which can in some way, be used to fulfil certain human needs. It comprises many elements that can be divided into two main categories: (a) natural land resources (b) artificial land resources. The first category constitutes the largest group and includes sub-groups such as climate, relief/landforms, vegetation, soils, water and wildlife (FAO, 1993a). The second category includes the products of past human activities such as dikes, polders, roads, canals and terraces (Vink, 1975).

2.5.1 Climate

Climate covers a range of factors including precipitation, temperature, sunshine, wind, humidity and cloudiness. Many of the land resources have been, and are,

influenced by climate during their formation. Climate is one of the genetic factors in the formation of relief (topography) and soils. It is the main agent in determining water balance in hydrology and geohydrology. Climate largely determines the nature of the natural vegetation in any given area, interactions between climate, relief and soils are particularly important for land use (Young, 1978). Temperature and water are the major factors that govern crop distribution (in both space and time). In combination with solar radiation, these factors condition the net photosynthesis and influence the rates at which plants accumulate dry matter and accomplish the successive development stages, according to the rates and patterns which are specific to cultivated plants (FAO, 1993a). Precipitation differs considerably in different parts of the world, and is a dominant factor in determination of land uses. Distribution of precipitation and even lack of precipitation can to some extent be corrected by irrigation (Vink, 1975).

The “*length of growing period*” has been used as a framework for the assessment of climatic resources (FAO, 1979; 1984). It is defined as the period in which temperature and moisture permit crop growth. The inventory of climatic resources allows; a differentiation of an area into reference thermal zones, reflecting the geographical and seasonal distribution of the prevailing temperature regimes; a differentiation of an area or region into reference Length of Growing Period (LGP) and LGP-pattern zones, reflecting the prevailing moisture regimes and including the year-to-year variations; a quantification of potential yields (of crops, livestock and fuelwood) that can be attained under constraint-free

conditions; and an assessment of various agroclimatic constraints in order to take into account agricultural land use possibilities and yield losses likely to occur.

2.5.2 Soils

“*Soil*” is a three dimensional body occupying the uppermost part of the earth’s crust and having properties differing from the underlying rock material as a result of interactions between climate, living organisms (including human activity), parent material and relief over periods of time and which is distinguished from other ‘soil’ in terms of differences in internal characteristics and/or in terms of gradient, slope-complexity, microtopography, stoniness and rockiness of its surface (Brinkman and Smith, 1973).

Soil resource is an essential part of land resources which limits land use. Soil conditions vary widely as climate conditions and can have a great influence on agricultural land use. Soil resources are studied in soil survey, which is taken as the most essential part representing all other land resources. Soil maps for land use planning are made with many different scales, varying from very small (1:5 million) to very large (1:5 thousand). The scale is very important as it has direct correlation with the detail with which field investigations are carried out. The maps on different scales are applicable to different kinds of land use planning. The detail and usefulness for planning are most properly expressed by the use of the “basic mapping unit” and the “basic planning unit” (King and Killingbeek, 1990). These terms respectively indicate the smallest area that can be indicated on

the map and the smallest area on this map which is sufficiently reliable to be used as a planning unit.

2.5.3 Water

Next to the soil, “water” is by far most important land resource which determine land use, it is simultaneously relatively stable, and rather easy for man to manipulate. In the whole world fresh water is a scarce resource (Douglas, 1994). Under natural conditions flowing water carries different quantities of solid materials, depending on the kind of climate, relief, lithology, soils, vegetation in the source areas and on the kind of action present in the different parts of the stream (upper, middle and lower). Plants, animals and men use water as an agricultural resource. Part of this water is temporarily stored in their tissue. A large part is, however, returned to the hydrological cycle through transpiration, which together with direct evaporation from free water and land surfaces, is returned to the atmosphere as “evapotranspiration”.

Ground water is intimately connected with the soils. Excess of ground water leads to insufficient air in the soils and is therefore deleterious to many plants. It may be caused by excess precipitation on soils of poor permeability. Excess surface water is a landscape characteristic which is intimately connected with the periodicity on the flow of rivers as well as with local relief. Intensive drainage may therefore be necessary. Land use types are strongly determined by water and water availability will determine the type of crop suitable to be grown in an area.

2.1.4 Vegetation

“Vegetation”, to some extent, is considered a land resource. It is a land attribute in so far as it is reasonably permanent or predictably cyclic. It may be natural or the result of past or present human activity. Vegetation often exerts a great influence on the present and future uses of the land by man (Young, 1974).

Vegetation, which is important component of land resource includes: (a) natural forests, which produce timber, fuel wood and other forest products. (b) natural grazing lands in semi-arid areas (c) natural and semi-natural forests, and grazing lands which have obtained a degree of permanency and with nearly stable position in the ecosystem of an area (d) natural or semi-natural vegetation which conserves important species and acts or may act as “gene-centers” for future plant breeding. (e) natural or semi-natural vegetation which in some way or other, fulfills a specially useful ecological function for example areas of enhanced stability and variability in an otherwise monotonous areas of intensive agriculture (f) vegetation which serves several roles in different kinds of recreation sheltering and aesthetic/visual roles.

2.5.5 Geology and relief

The nature and structures of geological formation have many indirect influences on agricultural land use. Geological formations provide the basic materials and structures for the parent materials of soils. Furthermore, geological formations have a strong impact on climate and hydrology. The influence of relief on agricultural land is multifaceted. Relief is the expression of the interaction of

several different phenomena and processes within the earth's crust and on its surface (Zink, 1989). Its forms and dimensions are primarily related to geological formations and to the climate, both past and present, which have either directly or indirectly acted upon these formations.

The indirect action of climates and the effect produced by the nature of geological formations on the relief occurs through the processes of weathering and soil formation and through the influence of living organisms including plants, animals and man. Relief is therefore typically connected with many other land resources. It influences climate, hydrology and is one of the most important factors in soil formation, including its negative aspect of soil degradation: both natural and accelerated processes of soil erosion are largely dependent on the nature of the relief.

Agricultural land use is strongly influenced by the size and shape of the relief forms. With regard to size, a division into three categories is often useful (Douglas, 1994). (a) macrorelief: relief forms with height differences of more than 50 m, (b) mesorelief: all relief forms with height differences between approximately 10 m and 50 m, (c) microrelief; relief forms with height differences of less than approximately 10 m. It should be noted that these categories are often superimposed on each other. Relief may further be divided into positive and negative forms, the former is elevation above a more or less arbitrary chosen reference plane, whereas the latter are depressions below this

plane: for example hills, hummocks, etc., and valley, watercourses, etc., respectively.

Relief shows many differences in shape, which in general has both a horizontal and a vertical component. Relief patterns include both hill patterns and drainage patterns, the dimensions of which may belong to any of the preceding size categories. According to Douglas (1994), hill and slope forms may be generalized as: (a) straight, flat, convex, concave, (b) long, short (slopes), (c) regular, irregular (slope forms surfaces) (d) narrow, wide (depressions, valleys). All of these factors have a direct impact on land management and may have a considerable significance for land improvement. They may to a great extent determine whether certain land utilization types are feasible in certain area or not.

2.5.6 Artificial land resources

Artificial land resources are an essential part of the land in terms of land use. Man, as a result of past efforts, has for example created land from sea and from inland waters; e.g. the polders of the Netherlands and of many other countries (Vink, 1975). Artificial land resources are found in nearly all parts of the world. They are often of very old and very specialized construction, completely adapted to the natural land conditions of an area by the age-old artisanship of the local people. These resources have been constructed by mankind through the ages and are still being constructed. Most of these must as well be carefully maintained by human efforts and organizations, the fact which constitute an essential difference between artificial and natural land resources (Young, 1978).

In addition, artificial land resources may lead not to the creation of new lands, but to the development of usable from non-usable land. Such usable land has been produced by centuries-old systems of irrigation, in arid countries such as Egypt, Iraq and Iran. Other artificial land features have considerable impacts on land use. Extension of urban areas and construction of highways and canals may have both favorable and unfavorable influences. The opening up of lands by roads and railways always has a clear influence on land use (Shanan, 1987).

Some examples of artificial land resources include: the paddy terraces in Asia (Ceylon and Indonesia); “khanats” or “khareez” subterranean irrigation canals of arid countries in Iran and Iraq; river embankments; man made canals and waterways which have become essential for both transport and drainage functions, and polders (in Netherlands, Belgium, etc.). Other examples are dams and barrages in rivers which serve both as a method of flood prevention and supply water for irrigation and for urban and industrial uses; and roads and rail roads for transportation of products and materials. All these are essential land resources for agricultural land use and for land development in general.

2.6. Impacts of irrigation

2.6.1. Impacts of irrigation on environment

The history of irrigated agriculture in the world, particularly in Africa, has not always recorded success. Some past schemes and some very recent ones suffered severe setbacks through silting, waterlogging, salinization as well as social and political changes. Some schemes proved excessively expensive (Altieri, 1990).

Possible environmental impacts of irrigation projects can be either direct or indirect although it is often difficult to draw a clear distinction between these two types. However, both direct and indirect impacts result into either direct or indirect land quality loss for crop production.

2.6.1.1. Direct Irrigation Impacts:

The direct irrigation impacts can be attributed to certain characteristics as regards irrigation. The causes of direct impacts can be linked to specific qualities about the project itself (NORAD, 1994). Those impacts resulted from project set-up like deforestation and scoring of surface soils that are rich in humus are regarded as direct impacts. These impacts are normally accelerating the rate of erosion of the surface layer of the soil.

2.6.1.2 Indirect Irrigation Impacts:

The indirect irrigation impacts arise from development processes ensuing from the project, or from changes of effects on the socio-cultural conditions and the management of the natural resources brought about by the new measures in some way or another (NORAD, 1994). Overpopulation, overutilization of land throughout the year, water-related problems, and changes of cropping pattern are normally regarded as indirect irrigation impacts.

Irrigation is often costly, technically complex and requires skill and experience to realize full benefits (Nahal, 1975). Moreover, it triggers changes in the entire major ecosystem regime (soil, water and atmosphere) which may have undesirable

consequences leading to desertification. Irrigation also interferes with the prevalent soil regime by introducing moisture in a quantity and sometimes quality which modifies the arid and semi-arid ecosystems, including the vectors of malaria and schistosomiasis. It is on record that the percentage of the population infected with schistosomiasis increased from 2 to 75 percent when perennial irrigation was introduced in Western Asia (Obeng, 1977). Again, interference with the hydrological cycle may cause underground flooding and waterlogging which with the deposition of salt, may defeat the entire purpose of irrigation. Fortunately, however, in most development projects which produce environmental hazards, timely precautions can minimize the adverse effects. Thus, efforts should be focused on maximizing the benefits of irrigation in arid and semi-arid zones on a sustained basis with provisions to overcome the detrimental effects on the environment and man himself.

2.6.2. Impacts of irrigation on salts and soil fertility

Research results on different irrigated lands in Tanzania has shown that nutrient deficiency in soils is in the form of total nitrogen and available phosphorus (Tarimo, 1995). On the other hand, salinity problems in Tanzania have been recognized for many years. The National Soil Service, (NSS) (1987) reported that soils of Kitivo village irrigation in Tanga were highly affected by salinity, which has led to a drastic decrease in yield. The study by Tarimo (1995) on soils of Mtibwa sugar estates, Morogoro, showed that among other factors, high salinity of the soils was the main problem responsible for decline in crop yields.

2.6.2.1. Salt affected soils

According to Reeve and Fireman (1967), salt affected soils are defined as soils having extensive concentration of salts or adsorbed sodium. These categories of soils exist in many countries particularly in the arid and semi-arid regions of Asia, Africa and South America. Although several studies have indicated weathering of primary minerals to be the primary source of nearly all soluble salts (Soil Survey Staff, 1951, and Richards, 1954), these are probably a few instances where sufficient salts have accumulated in place from this source alone to form salt affected soils. According to Richards (1954), the direct source of salts in the soils is the surface and ground waters, notably when they contain dissolved salts. Depending on the content of the soluble salts and adsorbed sodium or both, salt affected soils have been categorised into two major types, namely saline and sodic or alkaline soils, (NORAD, 1994).

Saline soils

Saline soils are soils which have soluble salts in such quantity that they interfere with growth of most plants. Saline soils are usually friable and may be recognized by presence of white salt crusts on the surface or by an oily looking surface devoid of vegetation (Soil Survey Staff 1951 and Allison, 1964). The high salt concentration keeps the soil in flocculated condition (Richard 1954 and James et al., 1982). The permeability of these soils to water and air are generally comparable to those of normal soils (Abrol et al., 1988). According to Oram and Dumsday (1990), climate, geomorphology and land use are important factors for tropical and sub-tropical salinity problems.

Massoud (1974), pointed out that an estimate of 150 million hectares of potential rice lands in the tropics and sub-tropics were affected by salinity. Salinity was the main constraint to high rice yield in deltas, estuaries and coastal fringes in the humid tropics. It also caused a serious problem in arid and semi-arid areas (Ponnameruma, 1972). Although rice and onions are reported as moderate salt-tolerant crop, no rice or onion variety can withstand high salinity throughout their growing cycle (De Datta, 1981). Soil solutions high in sodium chloride content and with electrical conductivity of 6 - 10dS/m are harmful to rice and onions plants and cause as much as 50% decrease in yield.

Sodic soils

Sodic or alkaline soils are those soils with sufficiency exchangeable sodium interfere with the growth of most crop plants, either with or without appreciable quantities of soluble salts. The presence of excessive amount of exchangeable sodium in the soils promotes the dispersion and swelling of clay minerals (FAO, 1985a). As the proportion of exchangeable sodium increases, the soils tends to become dispersed, less permeable to water and air, exhibit poor tilth and the soil structure becomes unstable (Allison, 1964, FAO, 1985a, Abrol et al., 1988). The dispersion reduces soil porosity, whereas swelling reduces pore size.

In Tanzania, a study conducted by Kaboni (1996) on the origin and characteristics of salt affected soils in Mafiga-Chamwino lowland area, Morogoro, showed that, almost all soils along the Ngerengere River flood plain were highly affected by soil sodicity problems. The study also revealed that the area was faced with two main sources of

salts namely; the surface and ground water. However, the chemical composition of both surface and ground water varies from one source to another.

2.6.2.2. Soil fertility degradation

Soil fertility is the major component of soil productivity. It is defined as the status of the soil with respect to the amount and availability to the plant nutrient elements necessary for optimal growth of a specified crop (Ponnamperuma, 1975). The term soil fertility is cast here to encompass not only essential plant nutrients but also aspects of soil structure, including water holding capacity and biological activities that influence both efficiency of use and sustainability of the resources (Pieri and Steiner, 1997). According to Neue and Snitwongse (1988) adequate supply of organic matter is important in soil fertility because it is the main source of available nitrogen that holds a key role in the productivity of the crops.

Soil fertility degradation in irrigation projects is a global process, but sub-Saharan Africa is affected most (Oldeman *et al.*, 1991). This is because most of the soils in sub-Saharan Africa, especially in the arid and semi-arid zones south of Sahara, are highly weathered and inherently impoverished in plant nutrients, soil organic matter and water retention capacity (Driessen and Dudal, 1991). Crosson and Anderson (1993) estimated that 320 million hectares (31% of all arable land) of arid and semi-arid sub-Saharan Africa are affected by different forms of human-induced soil fertility degradation. Buri *et al.*, (1999), conducted a study on the assessment of fertility status of flood plain soils in West Africa. The results showed that, the whole sub-region was found to be deficient in available phosphorous. For example, the

available phosphorous for humid equatorial forest was 9.84mg/kg, sub-humid Guinea savannah (8.01mg/kg), the dried northern sector of Sudan savannah (7.25mg/kg) and Sahel savannah (7.31mg/kg). They also reported that the total nitrogen levels were low throughout the sub-region particularly within the Sahel and Sudan savannah zones. Accordingly, even though the flood plain soils of West Africa were rich in total nitrogen than those of the inland valleys, they were still low in nutrient reserves, an indication of impoverishment in nutrient reserves.

2.6.3. Impact of irrigation on waterlogging

According to Shanani (1987), waterlogging is the result of a rise in the groundwater level. An area is generally classed as waterlogged if the water table lies less than 2m from the ground surface. When waterlogging reaches the root zone of the plants, yields diminish significantly because the roots need a soil-air-water environment to grow and cannot survive in free water. There are four principal causes of waterlogging which are: leakage from canals, wastage from distribution networks, over-irrigation and lack of suitable drainage facilities. Many examples of waterlogged areas can be found in the irrigated areas of the world – in India, Pakistan, the USA, Australia, North Africa and China (Iftikhar and Nasri, 1982).

There is evidence that irrigation has been practised along the Indus River system in Pakistan from 3000BC onwards. In the beginning, only narrow strips of land adjoining the riverbanks were irrigated. With time, irrigation has been extended. Pakistan contains probably the largest irrigation system in the world, and total about 15 million hectares are irrigated, of which more than 75% is served by government

canals. The physical layout of the canal systems and the methods of delivering water were evolved to fit the pattern of available supplies in the unregulated rivers, and to conform to the legal conditions and water allocations of the Pakistan-Indus Water Treaty of 1960. A basic canal design concept underlying the planning has been to achieve equitable water distribution with the minimum of human interference in the management of the system. Overall irrigation efficiencies, however, are relatively low-possibly about 30% and studies show that 35-45% of the water delivered by the canals never reaches the farmer's fields. Since the natural drainage is inadequate and artificial drainage was not provided in the early project years, extensive over irrigation combined with excessive leakage from the canals have led to rise in the water table (Iftikhar and Nasri, 1982).

2.7. Social-economic activities contributing to land use changes.

Many irrigation schemes are faced with social and economic problems arising from new skill requirements in farming, high investments in labour and capital and high population density. It has been demonstrated that sociological problems in irrigation schemes are more difficult to tackle than the technical ones. The adoption of a system which requires the combined presence of special managerial skills, a well organized administration, teams of engineers, researchers, economists, technicians, social workers and a farming population receptive to new methods and advice, often means a complete change in the life style of the farming population (United Nations, 1977). Overpopulation leads to over-utilisation of the land throughout the year, excessive deforestation, and water related problems hence land degradation. Overgrazing, charcoal/lime making, carpentry, pottery, gathering firewood and

building are among the social economic activities that can contribute to land use changes (Edwards *et al.*, 1990).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location

The study was conducted in Iringa and Morogoro regions Tanzania. The study area comprises of four villages, that is Ruaha Mbuyuni and Mtandika along Lukosi River, Msosa along Msosa River and Malolo along Mweha River. Lukosi, Msosa and Mweha are tributaries of Great Ruaha River as shown in Figure 3.1. The area is located between latitudes 7°34'S and 7°18'S and between longitudes 36°33'E and 36°20'E, on the leeward side of Udzungwa mountains. The altitude ranges from 520m to 1500m above the sea level.

3.1.2 Climate

The climate of the study area is semi-arid. The annual rainfall ranges from 430mm to 500mm (Hydrological section in Iringa and Morogoro region, 1999). Air temperature ranges from 26°C to 30°C. The area experiences maximum temperature in May to December and minimum temperature in January and April. The mean daily maximum temperature is 31.2°C while, the mean daily minimum temperature is 18.1°C. Annual evaporation rates vary from 1450mm/day to 1500mm/day. Relative humidity is lowest during the day. It ranges from 22.5% in the dry season to 87.9 % in the rainy season (Meteorological stations, 2000).

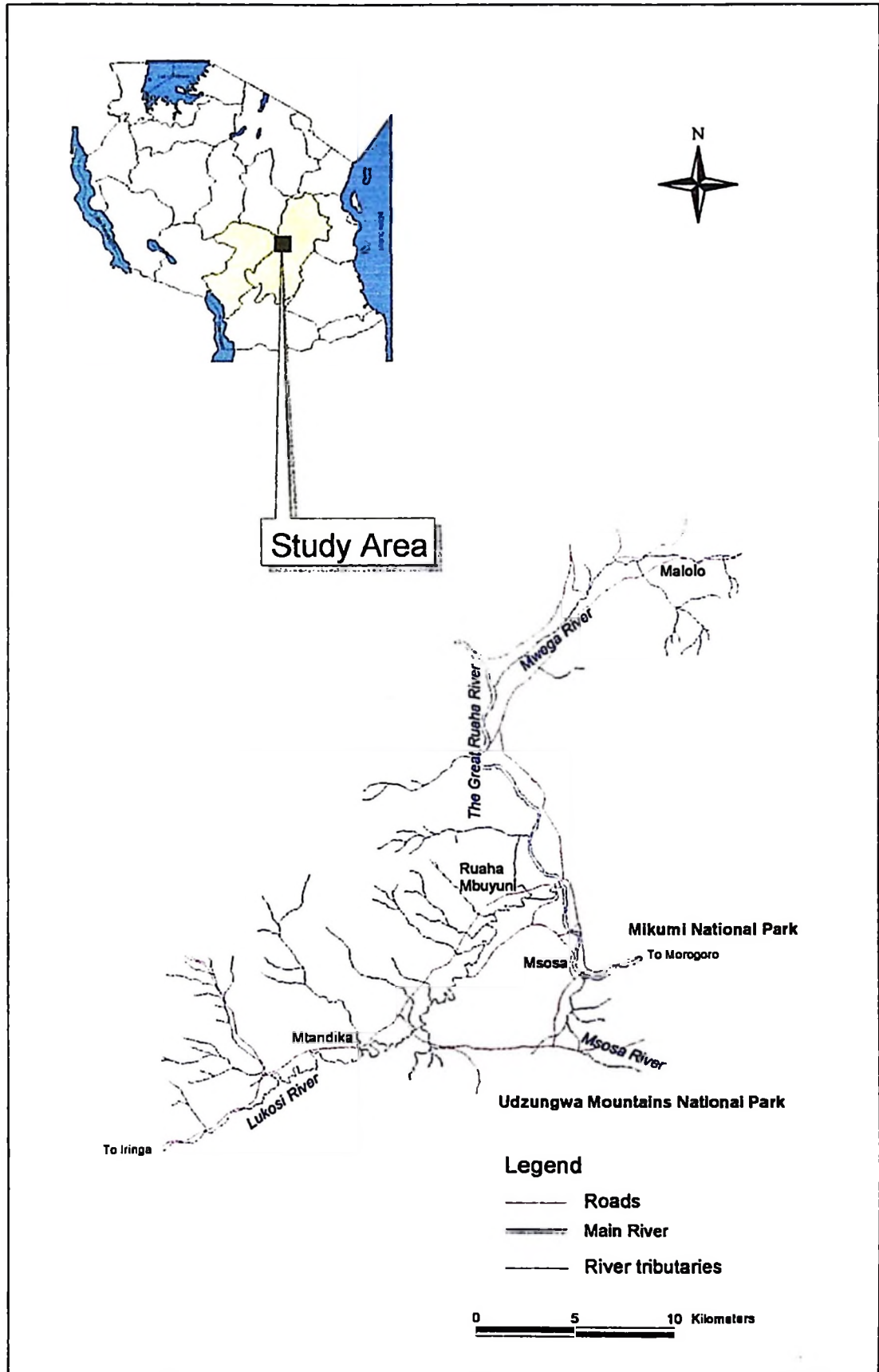


Figure 3.1 Location map of four villages around Ruaha Mbuyuni.

3.1.3 Hydrology

The major sources of irrigation water for the study area are as follows: For Ruaha Mbuyuni and Mtandika schemes is the Lukosi River while for Msosa and Malolo is Msosa and Mwega Rivers. Lukosi, Msosa and Mwega Rivers are tributaries of Great Ruaha River. The rivers have large catchment area, therefore the discharge is considerable. Maximum discharge of the Great Ruaha River is $180\text{m}^3/\text{s}$. The estimated difference in the lowest and highest water levels is 1.5metre (TIP, 1992). During big floods, the lowland areas are inundated and in rare cases, even the intake sites are flooded. Due to high current of water during rain seasons, riverbanks in front of the intakes are eroded.

3.1.4 Geology and Soils

The soils are mostly gambisols, on account of which they show severe swelling and shrinkage with changing moisture conditions, causing heavy fissuring and deep cracking on drying. In some parts, the soil is alluvial because it has been deposited in the low laying basins of the Great Ruaha River and its tributaries. The soils show a variation in texture within small areas but generally these soils range from coarse textured sand-loam to heavy cracking clay (National Soil Service, 1987).

3.1.5 Land use

The climate of the study area favours most of the upland and lowland crops. However, the main crops grown are paddy, maize, beans, onions and groundnuts. Crops that are given priority are onions and paddy. The cropping season starts with maize and paddy in January. Available irrigation water has to supplement rain, after

harvesting maize, and paddy in April onion is transplanted. In October, the canals are often dry, therefore, only about 10% of the area are cultivated between September, and October. Due to climatic condition and low soil fertility, the land use intensity is not very high (TIP, 1992). In the dry season, the scarcity of water restricts land use. There are some farmers who use small pumps to irrigate outside the schemes. Some of the farmers pump water from Lukosi River while others do the same from Great Ruaha River. Lowland paddy is cultivated in basins having permanent bunds. Upland crops, maize and onion are mainly cultivated in borders with temporary earthen bunds, whereby the land is divided into small plots of different sizes. To ease the hiring exercise, plots have been divided in a way that every plot has its hiring price (Village chairperson, Person communication, 2000).

3.2 Data collection

3.2.1 Primary data

3.2.1.1 Aerial photograph interpretation

Three sets of aerial photographs (1955, 1976, 1999) at a scale of 1:30,000 were used in this study. These sets were interpreted on a mirror stereoscope and was done based on interpretation elements and characteristics described by Dent and Young (1981) and Lillesand and Kiefer (1987), and these include the tone, shape, size, pattern, texture, shadows, site and association of objects and features. Then the land use maps of the study area for those years were prepared.

3.2.1.2 Rate of irrigation expansion and impact to changes in land use

The study involved the production of land use classification of the study area of different years against which the analysis of historical changes in land use due to irrigation activities was carried out. Spatial and qualitative data such as major land use categories and quantitative data such as size of cropped area, forest and settlement areas, were obtained from the aerial photographs. Maps produced were digitized and databases were formed in the computer. The digitized maps were used to determine the rate of irrigation expansion in relation to cleared land for cultivation and changes in land use/land cover using GIS-ARC-INFO/VIEW. Also the change detection matrix were performed by overlying the maps for the year 1955 and 1976 and 1976 and 1999 in order to obtain a class to class changes (ESRI, 1995).

3.2.1.3 Questionnaire survey and analysis

A survey was conducted to collect information on the historical changes in natural resources and socio-economic activities responsible for land use changes and natural resources degradation in the area. The information was obtained by interviews and inquiries based on a questionnaire shown in Appendix 1. In order to get a manageable sample size at an affordable cost and the time available, 5% of the households in each village were randomly chosen and surveyed. A total of 50 people were interviewed from four villages. The obtained data were organized into manageable units and analysed by using the statistical package for social sciences (SPSS) computer program.

3.2.1.4 Ground truthing

Ground truthing (field verification) of the study area was performed by using topographic maps and by doing reconnaissance survey. A global positioning system (GPS) was used to locate selected ground control points and types of present land use/land cover were recorded for each point.

3.2.1.5 Soil sampling procedure

By using the topographic sheet of the study area (1:50,000), a general field survey was conducted in which two villages (Ruaha Mbuyuni and Msosa) were selected for the study. These two villages were selected because they are closer and therefore soil samples could be taken easily at affordable cost and time. Ruaha Mbuyuni has two fields namely Mhinzi and Ilongo while Msosa has three fields namely Kikwale, Kigamboni and Madera. By using aerial photographs, topographic sheets, global positioning system (GPS) and ground evidences, observation pits (Figure 3.2) were located in all fields at the most useful and representative sites. According to Dent and Young (1981), the representative site is the point that represent the real situation of the field to be surveyed, the point should not be located on anything that can influence the soil physical and chemical properties e.g. under trees or on anthills.

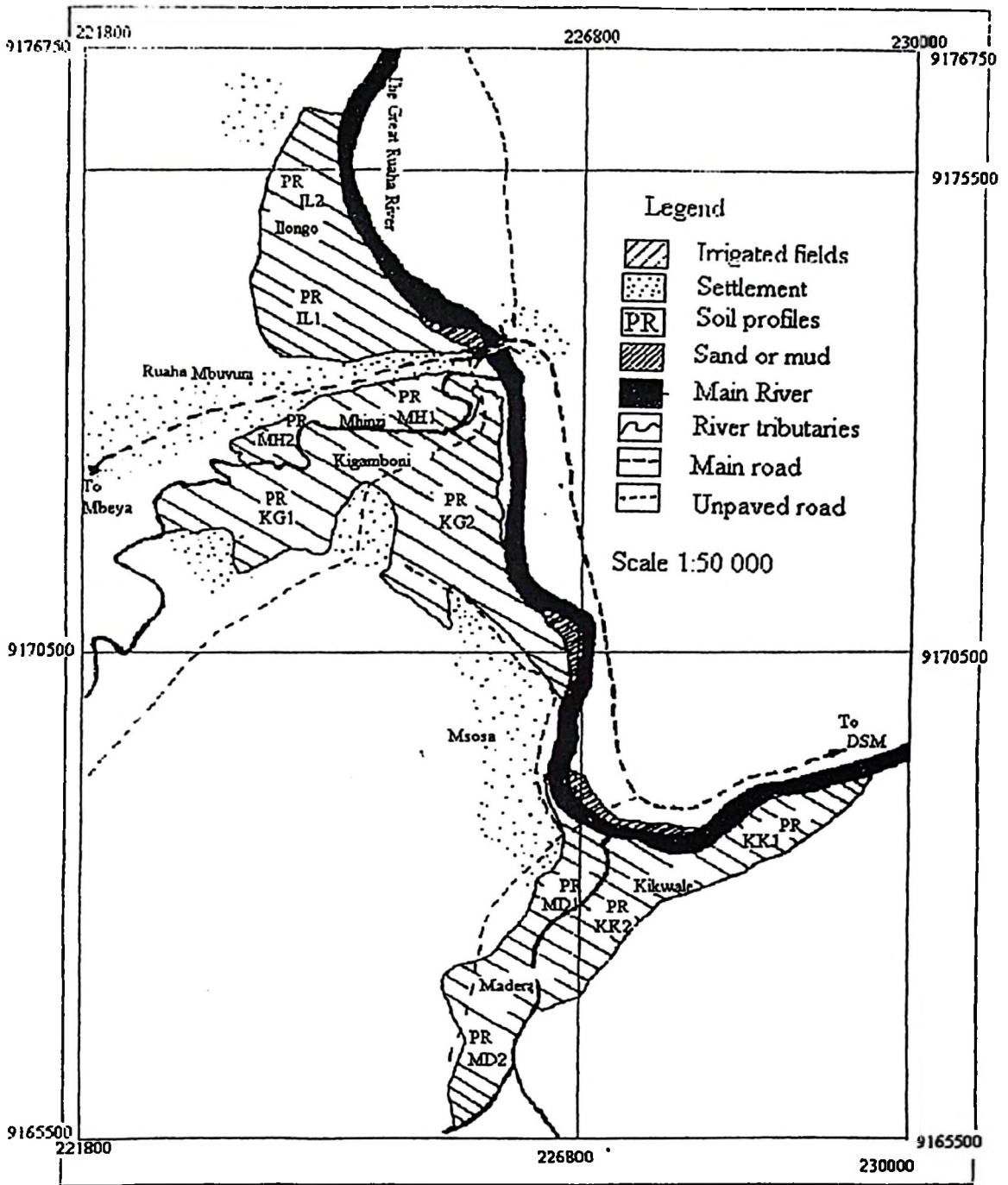


Figure 3.2: Irrigated fields in Msosa and Ruaha Mbuyuni villages and soil profiles

3.2.1.6 Soil chemical and physical properties

Stratified random sampling (Petersen and Calvin, 1986) was conducted in the five selected fields. In order to obtain a general trend in to the subsoil two representative pits were dug in each field. Both disturbed and undisturbed soil samples were collected from 0-15 cm, 15-30 cm, 30-45 cm, and 45-60 cm soil depths for physical and chemical laboratory analyses. The reason for sampling soil to a depth of 60cm was that the rooting depth of major crops grown in the area (rice and onions) does not exceed 60cm (Doneen and Westcot, 1988, Doorenbos and Pruitt, 1977).

The following soil chemical and physical properties were determined:

- (i) **Particle size distribution:** Particle size distribution is a measurement of the size distribution and individual particles in a soil sample. Particle size distribution of the soil sample was determined by the Bouyocous method as described by Juo (1979).
- (ii) **Bulk density:** Soil bulk density is the ratio of the mass of dry solids to the bulk volume of the soil. The bulk volume includes the volume of the solids and the pore space. The mass is determined after drying and obtaining the constant weights at 105°C. The bulk density of the soil samples was determined from undisturbed soil samples using the core sample method (Blake and Hartage, 1986);
- (iii) **Soil pH:** Soil pH is a measure of the activity of ionised hydrogen in the soil solution. Soil pH of the soil samples potentiometrically in 1:2.5 soil/water ratio as described by MacLean, (1982);
- (iv) **Organic matter content:** The organic matter content of the soil was indirectly obtained through multiplication of the organic carbon concentration by 1.724.

Organic carbon was determined by the wet combustion of Walkley and Black Method as described by Nelson and Sommers (1982).

(v) **Total Nitrogen:** Total available nitrogen of the soil samples were determined by Macro-Kjedahl digestion-distribution method as described by Bremner and Mulvaney (1982).

(vi) **Available Phosphorous:** Available phosphorous of the soil samples was determined by Bray and Kurtz 1 procedure as outlined by Oslen and Sommers (1982).

(vii) **Cation Exchange Capacity:** Cation exchange capacity is a measure of the quantity of readily exchangeable cations neutralising negative charge in the soil. The CEC of the soil samplee were obtained using the Macro-distillation method as described by Thomas (1982).

(viii) **Exchangeable cations:** Exchangeable cations are those ions that can be exchanged by a cation of added salt solution. The exchangeable cations (Ca, Mg and Na) of the soil samples were determined from NH₄Oac leachate by atomic absorption spectrophotometer (Hesse, 1971).

3.2.1 Secondary data

Secondary data such as background information of the study area was obtained from agricultural offices. The census information, population records and some employment figures of the study area between 1968-1988 were collected from the Bureau of Statistics, Dar-es-Salaam. Aerial photographs for the years 1955, 1976 and 1999 at a scale of 1:30,000 and topographic sheets at a scale of 1:50,000 were obtained at the department of Land Survey and Mapping in Dar-es-Salaam.

CHAPTER FOUR

4.0. RESULTS AND DISCUSSION

4.1. Impact of irrigation on land use

4.1.1 Land use/land cover types of the study area between 1955 and 1999

Land cover classification in Tanzania is yet to be standardised. This situation makes it difficult to compare different studies and use previous studies as baseline for subsequent studies (Kikula, 1997). In this study broad classes of land use/land cover established by interpretation of aerial photographs of the study area were, forest, woodland, scrub, cultivated areas (irrigated and rainfed), abandoned fields, riverine vegetation, settlement and main river. Forest is vegetation consisting of large and dense trees with definite bore or trunk, can be natural or artificial, while woodland is vegetation consisting of trees and shrubs but not denser as forest. Scrub bushland is vegetation consisting of stunted trees and shrubs. Shrubs are trees that do not have definite bole or trunk (Kiunsi, 1994). Cultivated area refers to land cultivated in the year of photography and abandoned field refers to land cultivated 1-3 years before the year of photography (regenerating). Riverine vegetation is the vegetation along the river, may be forest, scrubs or wood and settlement is the area consisting of buildings where people stays. The dissimilarities among the remotely sensed data (acquisition dates and spatial resolution or scale) influenced the accuracy of classification.

Table 4.1 shows the area coverage of land cover/land use types in the study area in 1955, 1976 and 1999. The spatial distribution of the land use/land cover types in the study area for 1955, 1976 and 1999 is shown in Figures 4.1 to 4.3 respectively.

Table 4.1: Areal coverage of land cover/land use types in the study area in 1955, 1976 and 1999

Land use/Land cover	1955		1976		1999	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	1422.8	2.567	1333.8	2.407	1014.7	1.83
Irrigated fields	488	0.88	2544.8	4.593	4073.4	7.352
Rainfed fields	266.3	0.481	253.6	0.458	950.3	1.715
Abandoned fields	0	0	0	0	92.5	0.167
Riverine vegetation	5042	9.1	3879.5	7.00	1870	3.375
Scrub	45203	81.584	44481.6	80.28	45067.9	81.339
Woodland	2175.9	3.927	1645.6	2.97	427.9	0.772
Settlement	363	0.655	822.5	1.484	1463.3	2.641
Main river + sand or mud	446	0.805	445.6	0.804	447	0.807
Total area	55407	100	55407	100	55407	100

Source: Aerial photographs, 1955, 1976 and 1999.

Table 4.1 shows that irrigated fields have been increasing and cover 0.88%, 4.593% and 7.352% of the study area for the year 1955, 1976 and 1999 respectively. Rainfed fields cover 0.481%, 0.458% and 1.715% for the same periods. Riverine vegetation was observed to decrease and occupied 9.1%, 7.0% and 3.375% of the study area for the year 1955, 1976 and 1999 respectively. Irrigated fields have increased from 0.88% to 7.352% between 1955 to 1999 and riverine vegetation has been decreasing from 9.1% to 3.375%. However, looking at Figure 4.1 to 4.3 most of the riverine area has been converted into irrigated fields.

Equally important to note from Table 4.1 is that settlement cover was extensive occupying 0.655%, 1.484% and 2.641% of the study area for the year 1955, 1976

and 1999 respectively, the increasing trend of settlement suggests that people shifted for irrigation purposes have also contributed to the increase of settlement area.

Table 4.1 also shows that scrub bushland covers a large part of the study area (81.584%, 80.28% and 81.339%) for the year 1955, 1976 and 1999 respectively and this is due to the fact that this area is very dry with very shallow soils and it consists of stunted trees and bushes. However, this can be observed in Figure 4.1 to 4.3 that most of the agricultural activities are concentrated along the riverbanks where traditional irrigation is possible, soils are deep and suitable for agriculture.

Woodland and forest were observed to decrease throughout this period. Woodland occupied 3.927%, 2.97% and 0.772% and forest occupied 2.567%, 2.407% and 1.83% of the study area for the year 1955, 1976 and 1999 respectively. Though cultivation has been observed to be responsible for decline in woodland and forest but it seems that there are other causes of deforestation other than cultivation. Other causes of forest and woodland depletion mentioned by farmers were cutting of trees for building materials, lumbering, charcoal production and destruction caused by forest fires. Irrigation activities are also responsible for forest and woodland depletion as farmers settled for irrigation purposes used trees for building, firewood and charcoal. Abandoned fields were observed in 1999 and cover only 0.168% of the study area and the reason might be due to land scarcity in the study area, therefore people does not abandon fields.

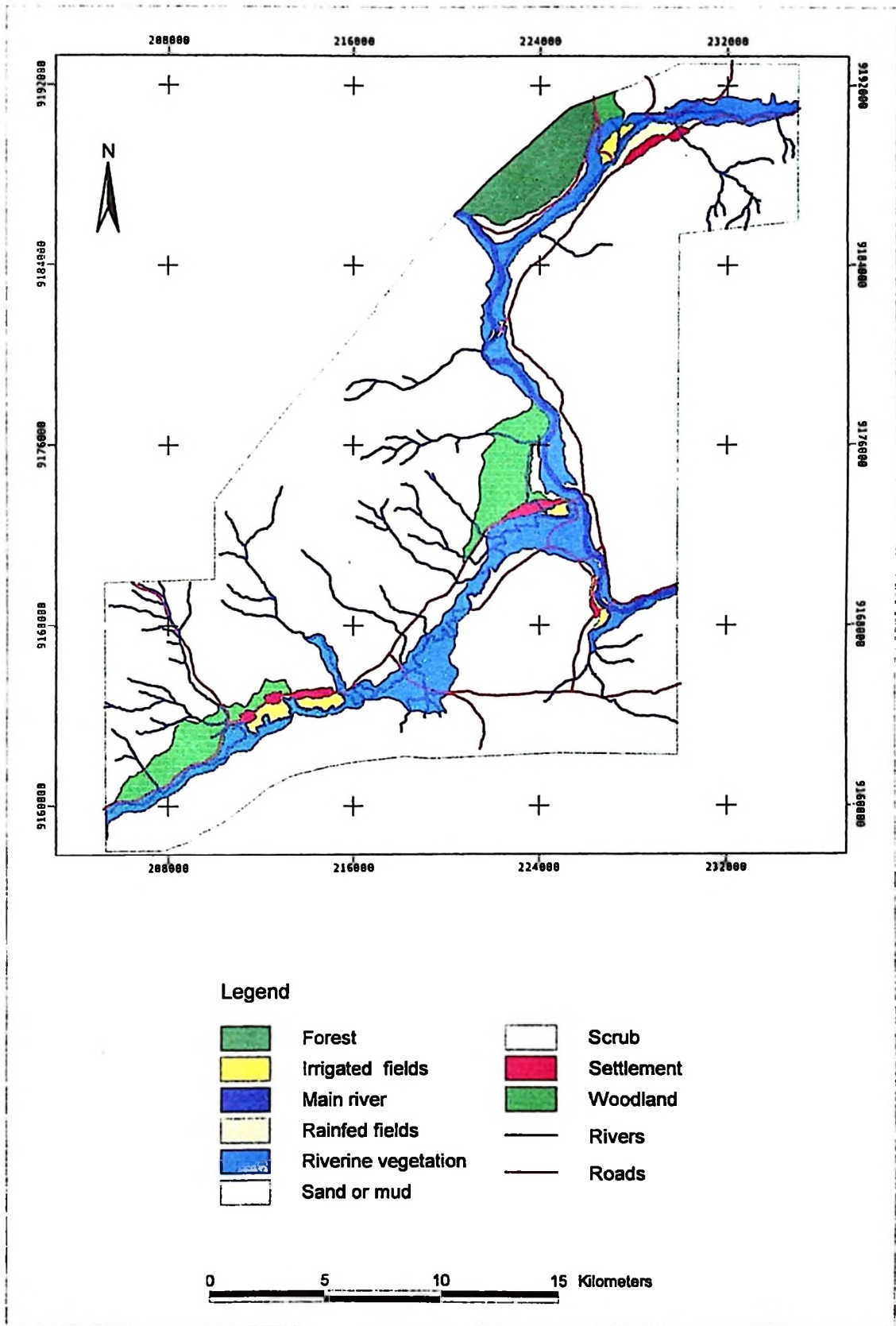


Figure 4.1 Land use map for 1955 of four villages around Ruaha Mbuyuni .

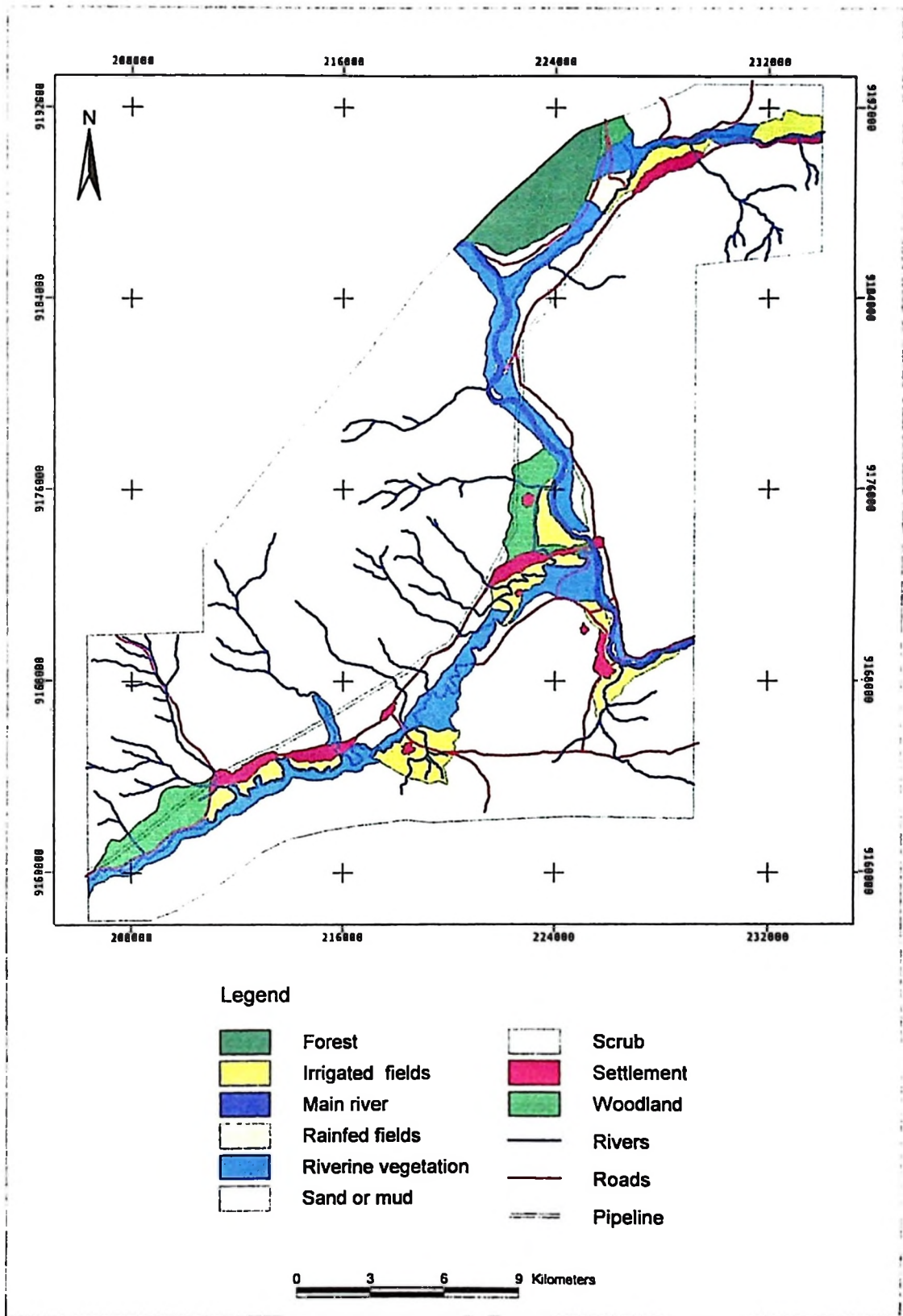


Figure 4.2 Land use Map for 1976 of four villages around Ruaha Mbuyuni.

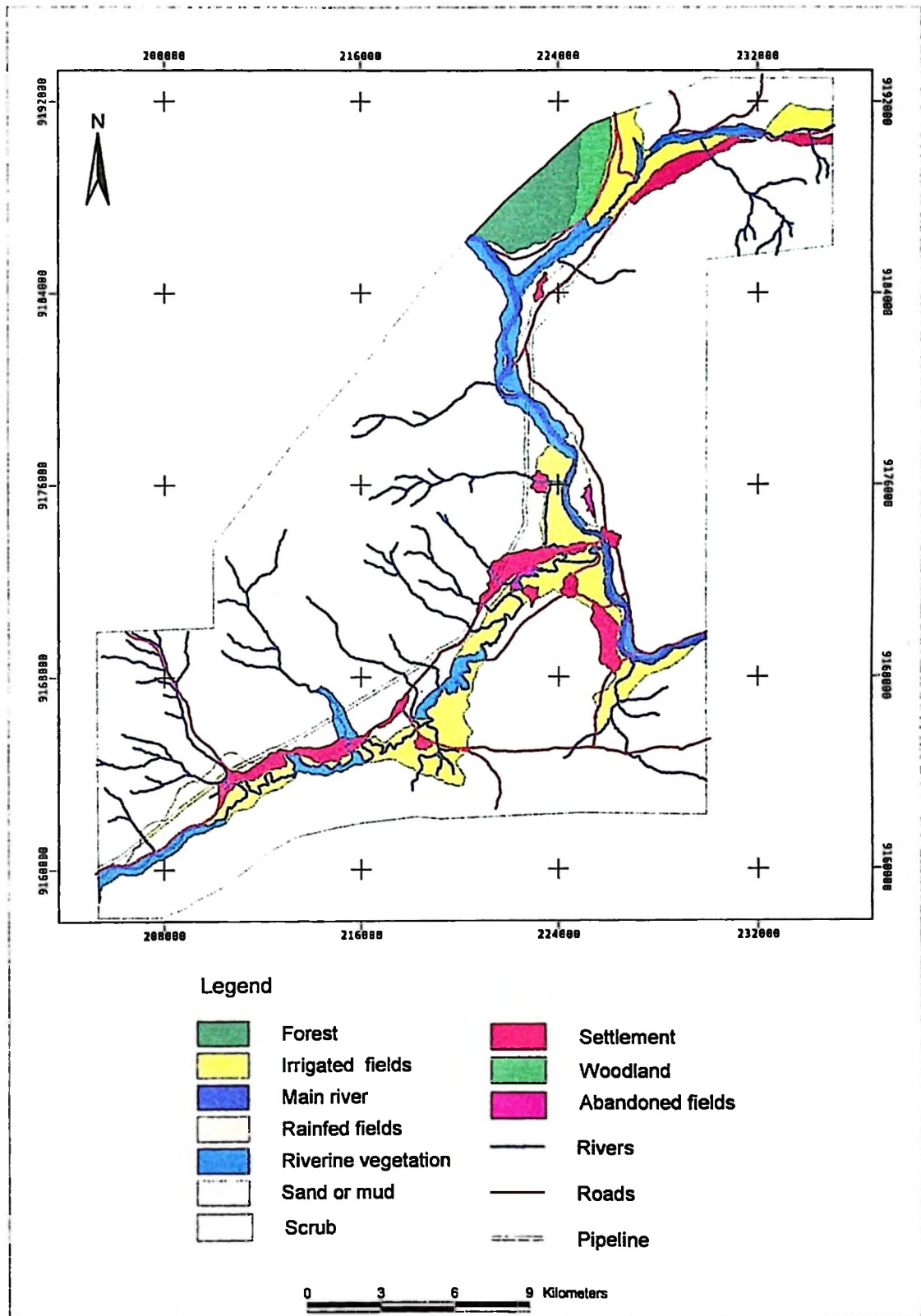


Figure 4.3 Landuse Map for 1999 of four villages around Ruaha Mbuyuni.

4.1.2 Changes in land cover/land use types between the two temporal periods (1955 to 1976 and 1976 to 1999)

The temporal periods, 1955 to 1976 and 1976 to 1999 have experienced considerable land cover/land use changes. Table 4.2 shows changes in areal coverage of the different land cover/land use types in the study area for both temporal periods.

Table 4.2: Changes in areal coverage of the different land cover/land use types in the study area between 1955 and 1999

Land cover/land use	Temporal Period			
	1955-1976 (21years)		1976-1999 (23years)	
	Area (ha)	Rate (ha/yr)	Area (ha)	Rate (ha/yr)
Forest	-89.0	-4.24	-319.1	-13.874
Irrigated fields	+2056.8	+97.94	+1528.6	+66.46
Rainfed fields	-12.7	-0.605	+699.4	+30.409
Abandoned fields	0	0	+92.5	+4.022
Riverine vegetation	-1162.5	-55.36	-2009.5	-87.37
Scrub	-721.4	-34.352	+586.3	+25.491
Woodland	-530.3	-25.252	-1217.7	-52.943
Settlement	+459.5	+21.88	+640.8	+27.86
Main River + sand or mud	-0.4	-0.019	+1.4	+0.07

NB: (+) Indicates increase and (-) indicates decrease.

It is evident from Table 4.2 that, riverine vegetation cover is decreasing at a faster rate (about 55.36 ha/yr for the period between 1955 and 1976 and 87.37 ha/yr for the period between 1976 and 1999) while cultivated area is showing a rising trend (about 97.335 ha/yr for the period between 1955 and 1976 and 99.36 ha/yr for the period between 1976 and 1999). The table shows that cultivated area is divided into two types, i.e irrigated fields and rainfed fields. Irrigated fields have been observed to increase at a faster rate (97.94ha/year for the period between 1955 and 1976 and

66.46 ha/year for the period between 1976 and 1999). The rate of expansion of irrigated fields was observed to be higher for the temporal period 1955 to 1976 than that of 1976 to 1999. The reason may be due to scarcity of land which can be irrigated by traditional means and therefore most of the land was already occupied by the year 1976. Rainfed fields were observed to decrease for the temporal period 1955 to 1976 (-0.605ha/year) and increased for the temporal period 1976 to 1999 (30.409ha/year). The increase of rainfed fields in the temporal period 1976 to 1999 may be due to opening of new maize farms in Mtandika in the area which is not easily irrigable by traditional means.

Table 4.2 also shows that settlement has increased at the rate of 21.88ha/year for the temporal period between 1955 to 1976 and 27.86ha/year for the period between 1976 to 1999. Settlement has observed to increase more for the period 1976 to 1999 compared to the period 1955 to 1976, the reason for this might be due to villagization which took place in 1972 which ordered people to settle together in the villages.

Woodland and forest have been observed to decrease for both temporal periods. Woodland has been decreasing at a rate of 25.252ha/year and 52.943ha/year and forest has been decreasing at a rate of 4.24ha/year and 13.874ha/year for the year 1955 to 1976 and 1976 to 1999 respectively. The rising trend of scrub bushland cover for the temporal period 1976 to 1999 suggests that there is regeneration in the areas where forests and woodland were depleted due to cultivation and other land uses.

4.1.3 Extent of land use/cover change for the two temporal periods 1955 to 1976 and 1976 to 1999

Figures 4.4 and 4.5 shows the overlay maps between 1955 - 1976 and 1976 – 1999 respectively and Tables 4.3 and 4.4 shows a class to class analysis of land cover/land use changes in the study area for the two temporal periods 1955 to 1976 and 1976 to 1999 respectively

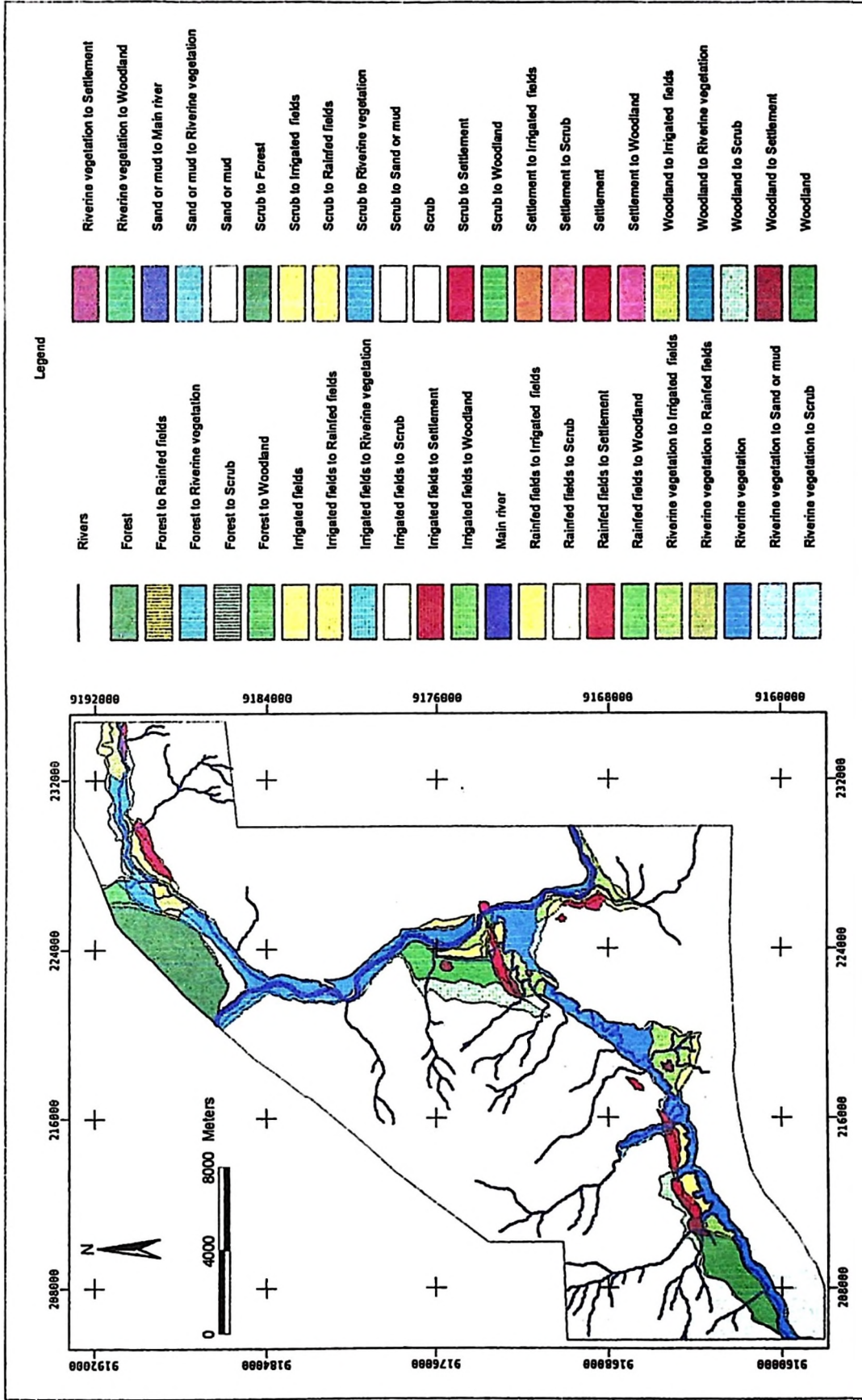


Figure. 4.4. Land use changes for four villages around Ruaha Mbuyuni, between 1955 and 1976.

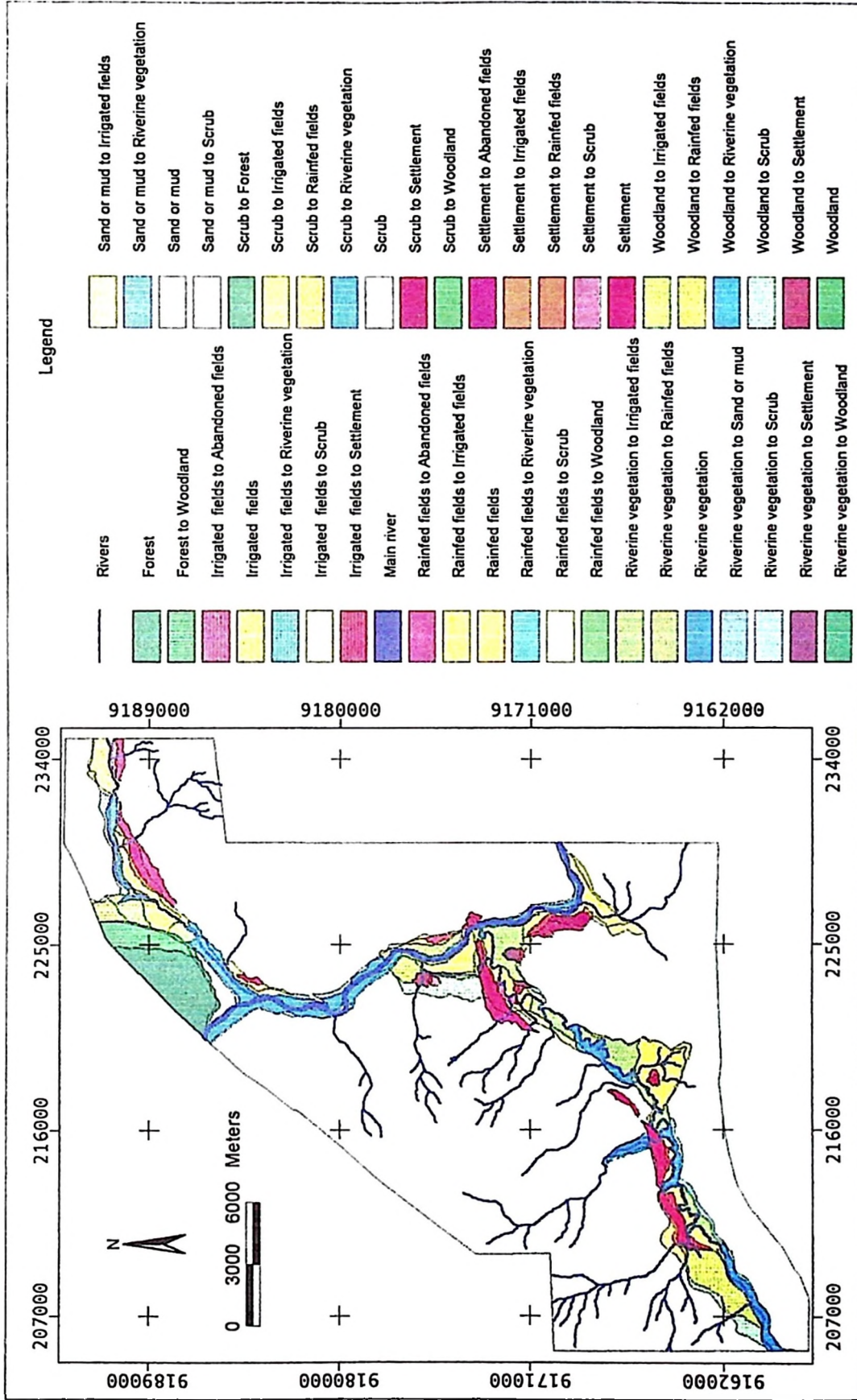


Figure. 4.5 Land use changes for four villages around Ruaha Mbuyuni, between 1976 and 1999.

Table 4.3. Change from one class to another for the year between 1955 and 1976

Land use/cover			
From 1955	To 1976	Area (ha)	%
Forest	Forest	1332.8	2.4
Forest	Rainfed fields	11	0.02
Forest	Riverline vegetation	25	0.04
Forest	Scrub	24	0.04
Forest	Woodland	29.9	0.05
Irrigated fields	Irrigated fields	377.6	0.68
Irrigated fields	Rainfed fields	49.5	0.09
Irrigated fields	Riverline vegetation	56.4	0.1
Irrigated fields	Scrub	1.7	0.003
Irrigated fields	Settlement	2.6	0.005
Irrigated fields	Woodland	2.2	0.004
Main river + sand/mud	Main river + sand/mud	446	0.8
Sand/mud	Scrub	0.4	0.00
Rainfed fields	Irrigated fields	238.9	0.43
Rainfed fields	Scrub	11.3	0.02
Rainfed fields	Settlement	9.4	0.02
Rainfed fields	Woodland	5.5	0.01
Riverline vegetation	Irrigated fields	1227.3	2.22
Riverline vegetation	Rainfed fields	103	0.19
Riverline vegetation	Riverline vegetation	3100.9	5.6
Riverline vegetation	Scrub	392	0.71
Riverline vegetation	Settlement	117	0.21
Riverline vegetation	Woodland	0.8	0.00
Scrub	Irrigated fields	329.8	0.6
Scrub	Rainfed fields	90.6	0.16
Scrub	Riverline vegetation	419.8	0.76
Scrub	Scrub	44280.8	79.92
Scrub	Settlement	169.6	0.31
Scrub	Woodland	11	0.02
Settlement	Irrigated fields	12.5	0.02
Settlement	Scrub	19	0.03
Settlement	Settlement	326.3	0.59
Settlement	Woodland	4.3	0.008
Woodland	Irrigated fields	48.4	0.09
Woodland	Riverline vegetation	38	0.07
Woodland	Scrub	663.7	1.2
Woodland	Settlement	137.5	0.25
Woodland	Woodland	1290.5	2.33
Total		55407	100

Source: Aerial photographs, 1955 and 1976

Table 4.4. Change from one class to another between the year 1976 to 1999

Land use/ land cover		Area (ha)	%
From 1976	To 1999		
Forest	Forest	958	1.73
Forest	Woodland	374.8	0.68
Irrigated fields	Abandoned fields	56	0.1
Irrigated fields	Irrigated fields	1913.4	3.45
Irrigated fields	Riverline vegetation	44	0.08
Irrigated fields	Scrub	74.2	0.13
Irrigated fields	Settlement	159.5	0.29
Main river + sand/mud	Main river sand /mud	445.6	0.8
Rainfed fields	Abandoned fields	32.2	0.06
Rainfed fields	Irrigated fields	148	0.27
Rainfed fields	Rainfed fields	33.7	0.06
Rainfed fields	Riverine vegetation	10.4	0.02
Rainfed fields	Scrub	21.3	0.04
Rainfed fields	Woodland	7.2	0.013
Riverine vegetation	Irrigated fields	1372.5	2.48
Riverine vegetation	Main river + sand/mud	1.6	0.00
Riverine vegetation	Rainfed fields	207.7	0.37
Riverine vegetation	Riverine vegetation	1603.5	2.89
Riverine vegetation	Scrub	460	0.83
Riverine vegetation	Settlement	63.6	0.12
Riverine vegetation	Woodland	28	0.05
Scrub	Forest	3.5	0.006
Scrub	Irrigated fields	374	0.68
Scrub	Rainfed fields	177.7	0.32
Scrub	Riverline vegetation	162.9	0.3
Scrub	Scrub	44091.4	79.58
Scrub	Settlement	518.4	0.94
Scrub	Woodland	11.4	0.02
Settlement	Abandoned fields	3.47	0.006
Settlement	Irrigated fields	3.3	0.006
Settlement	Rainfed fields	6	0.01
Settlement	Scrub	4.6	0.008
Settlement	Settlement	652.7	1.18
Woodland	Irrigated fields	337.8	0.61
Woodland	Rainfed fields	506	0.91
Woodland	Riverline vegetation	8.8	0.02
Woodland	Scrub	452.3	0.82
Woodland	Settlement	71.7	0.13
Woodland	Woodland	6.5	0.012
Total		55407	100

Source: Aerial photographs 1976 and 1999

As the main objective of this study is to assess the effects of irrigation activities on land use changes, from Figures 4.4 and 4.5 (the overlay of two maps i.e 1955 with 1976 and 1976 with 1999) it can be seen that irrigation activities have depleted riverine vegetation. Concentrating on changes involved the classes irrigated fields and riverine vegetation, Table 4.3 shows that 377.6ha (0.68% of the study area) remained irrigated fields by the year 1976 and there had been transformation of 1856.9 ha (3.36% of the study area) of the other classes into irrigated fields, out of this riverine vegetation constitutes about 66% (Appendix 3). Also evident from Table 4.4 (1976-1999) is that 1913.4ha (3.45% of the study area) remained irrigated fields by the year 1999 and there has been transformations of 2235.6ha (4.046% of the study area) of other classes into irrigated fields, out of this riverine vegetation constitutes 1372.5 ha or 61% (Appendix 3). The net result of transformations is depletion of 1840.1 ha and 2131.1 ha of riverine vegetation for the temporal period 1955 to 1976 and 1976 to 1999 respectively, out of which irrigated area contributed 66.6% and 64.4% for the two temporal periods respectively. Also Figures 4.4 and 4.5 shows that land use changes have taken place along the rivers where there is good land for agriculture. Tables 4.3 and 4.4 also shows that there was very small changes in the class scrub bushland to other classes, out of 45301.6ha and 45339.3ha of scrub only 1020.8ha (2.25%) and 1247.9ha (2.75%) was observed to transform into other classes for the year 1955 to 1976 and 1976 to 1999 respectively and this is due to the fact that, scrub occupy the area which has shallow soils and difficult to irrigate by traditional means. Mohammed (1985) also observed the same in Rukwa region along the shore of lake Tanganyika.

4.2 Socio-economic factors

4.2.1 Human population changes between 1967 to 1999

Human population changes in the study area as per previous population censuses are summarised in Table 4.5. The population increased from 2866 to 4999 people between 1968 and 1978 with an annual growth rate of 7.3%. From 1978 to 1988, the population increased from 4999 to 9174 people with an annual growth rate of 8.4%. By projection, using the annual growth rate of 8.4%, the populations from 1988 to 1998 will be 16877 people. Therefore, the population increased from 2877 to 16877 people between 1968 and 1998. The pace of population dynamics between 1968 and 1998 in the study area was shown to be very high.

Table 4.5 Human population changes in Ruaha Mbuyuni, Msosa, Mtandika and Malolo villages (1968-1998)

Year	Population	Annual growth rate(%)
1968	2886	-
1978	4999	7.3
1988	9174	8.4
1998	16877	

Sources:URT (1969, 1978 and 1988).

Results of questionnaire survey showed that of 50 respondents 23 (46%) originated from the study area i.e Ruaha Mbuyuni, Msosa, Mtandika and Malolo. 16% originated from Malolo, 10% originated from Ruaha Mbuyuni, 14 originated from Mtandika and only 8% originated from Msosa (Table 4.6). The rest of respondents 54% shifted into the study area because of different reasons as indicated in Table 4.7 below. Most of the people shifted into the study area because of either insufficient

rainfall in their place of origin and/or lack of irrigation water. Out of 14 respondent surveyed in Msosa, 71% shifted from Mbatwa and Kididimo in 1977 and this is because the Government ordered people to shift to Msosa after villagization as there was insufficient rainfall in their villages. Therefore, the Government ordered 125 families from Mbatwa and 10 families from Kididimo village to shift to Msosa and involve themselves in irrigated agriculture. However, the Government promised to assist those people to construct irrigation canals but it is unfortunately they did not meet their promise (Wansik, 1992). Also out of 13 people interviewed in Ruaha Mbuyuni 31% respondents shifted into Ruaha Mbuyuni due to lack of market for their onion crop in their place of origin. Onion crop is sold at Ruaha Mbuyuni at a good price because the area is situated along the main road from Dar-es Salaam to Mbeya. Therefore two factors namely, natural population growth and immigration into the study area may be responsible for the population explosion.

Table 4.6 Place of birth of respondents

Place of birth	Frequency	Percentage proportions of total respondent
Iringa	5	10
Kididimo	3	6
Malolo	8	16
Mbatwa	6	12
Mbuyuni	5	10
Mgowero	3	6
Morogoro Town	2	4
Msosa	4	8
Mtandika	7	14
Njombe	7	14
Total	50	100

Source: Survey data (2000)

Table 4.7 Reasons for shifting of respondents

Reasons for shifting	Frequency	Percent proportions of total respondent
Governmental order	10	20
Lack of markets	4	8
Irrigation activities	8	16
For work	3	6
For business	2	4
Not shifted	23	46
Total	50	100

Source: Survey data (2000)

4.2.2 Household major occupation and important socio-economic activities

The study showed that every body who is able to work engages himself in irrigated agriculture. Irrigation has been observed to be the main agricultural input in these villages. Table 4.9 indicates that 81.08% of the cropped land was under irrigation by the year 1999 and almost all respondents were observed to engage themselves in crop cultivation by irrigation. Out of 50 respondent households, (70%) were engaged in crop production only, the rest (30%) were engaged in both cultivation and other activities. (10%) were engaged in crop cultivation and paid labour, (8%) were engaged in crop cultivation and business, (6%) were engaged in crop cultivation and charcoal or carpentry work and (6%) in crop cultivation and small-scale enterprise (Table 4.8). Main crops grown include onions, maize, rice and groundnuts. Livestock keeping in the area is not well pronounced because of the threat of theft by Maasai (Village chairperson, person communication, 2000). The animals kept are chicken, ducks and goats. Chickens and ducks are kept for domestic use while goats are kept as insurance for the family when an urgent expenditure is required i.e. as a source of finance to the family.

The most common socio-economic activities in terms of cash earnings is fuelwood gathering followed by charcoal and carpentry. Small-scale industries such as local beer making, bee keeping and pottery are least practiced activities. Fuel gathering is the most practiced activity (86%) (Table 4.8) because it is the only source of fuel in the area for cooking. Very few people in the study area use charcoal as source of energy. Also building has observed to be among the socio-economic activities responsible for land use changes. Out of 50 respondents (56%) (Table 4.10) were observed to own houses built with poles and grasses. The extent of socio-economic activities such as fuelwood gathering, charcoal making and building can be related to irrigation activities because people settled for irrigation purposes requires fuelwood as a source of energy and trees for building.

Table 4.8 Major occupations of respondent households

Occupation	Frequency	Percent proportions of total respondent
Farming only	35	70
Paid labour + Farming	5	10
Business man + farming	4	8
Small scale enterprise + farming	3	6
Charcoal or carpentry + farming	3	6
Total	50	100

Source: Survey data (2000)

Table 4.9: Land distribution between irrigation and rainfed agriculture.

Type of land management (1999)	Area (ha)	%
Irrigated fields	4073.4	81.08
Rainfed fields	950.5	18.92
Total cultivated area	5023.9	100.00

Source: Aerial photographs, 1999

Table 4.10: Distribution of house construction materials

Construction material	Frequency	Percent proportions of total respondent
Wall		
Cement block	4	8
Burnt bricks	11	22
Unburnt bricks	5	10
Poles + mud	28	56
Mud	2	4
Roof		
Corrugated iron sheet	22	44
Grass + straw	28	56

Source: Survey data (2000)

4.2.3 Land cultivated for crop production and yield

Table 4.11 shows the distribution of farm size of respondent household heads. Most of the respondent own farms ranging from 0-6 acres (64%), while very few people (10%) own big farms (9 acres and above) whom hire out their farms to landless people. The small size of most farm holdings is due to the fact that there is scarcity of irrigable land in most of the study area and all-farming activities concentrates along the River, this can be seen from land use maps (Figures 4.1 to 4.3) and Table 4.1. Out of 54960ha of study area only 754.3ha (1.361%), 2798.4ha (5.057%) and 5023.7ha (9.067%) were observed to be cultivated for the years 1955, 1976 and 1999 respectively.

Differences in yields of crops were observed between the respondent's households and these differences were due to either farm location or soil management. For example in Msosa and Ruaha Mbuyuni the people who owns farms in Ilongo and Kigamboni get good yield than those with farms in Mhinzi, Kikwale and Madela. The survey showed that for 1999/2000 the average yields of maize were 1700kg/ha, 1650kg/ha, 940kg/ha,

648kg/ha and 687kg/ha for Ilongo, Kigamboni, Mhinzi, Kikwale and Madela fields respectively (Table 4.12). Also differences in yield were observed between rich and poor people and this is due to the fact that the rich can afford timely planting and application of enough fertilizers. However farmers have their own standard of wealth ranking, these include ownership of a retail shop, milling machine, size of irrigated farms and annual harvest of major crops (Table 4.13). Size of irrigated farm is the most valuable indicator of wealth of people in these villages, people with only rainfed fields are regarded as poor.

Table 4.11: Distribution of farm size of respondent household heads

Farm size	Frequency	Percent proportions of total respondents
0 – 3	19	38
3 – 6	13	26
6 – 9	10	20
9 – 12	3	6
12 – 15	3	6
15 and above	2	4
Total	50	100

Source: Survey data (2000)

Table 4.12: Average yield of maize and farm location (1999)

Farm location	Yield (kg/ha)
Ilongo	1700
Kigamboni	1650
Mhinzi	940
Kikwale	648
Madera	687

Source: Survey data (2000)

Table 4.13: Wealth ranking in the study area.

Wealth category	Indicator of wealth
Rich	Own > 9 acres of irrigated farm and produce > 100 bags of onions or > 50 bags of cereals or own milling machine.
Average	Own 3 -9 acres of irrigated farm and produce 40 – 100 bags of onions or 5 – 50 bags of cereals or own retail shop
Poor	Own < 3 acres of irrigated farm or own only rainfed farm and produce < 40 bags of onions or < 5 bags of cereals.

Source: Survey data (2000)

4.2.4 Constraints to crop production

Crop production constraints mentioned by the respondents include water scarcity, pest problems, low soil fertility status and low use of agricultural inputs due to unavailability, high cost and poverty (Table 4.14). The general response of the people to low land productivity was to move to a fresh piece of land and start irrigation by water pumps.

Table 4.14 Constraints to crop production

Constraints	Frequency	Percentage proportions of total respondents
Expensive inputs	8	16
Low soil fertility	21	42
Water problems	19	38
Pest problems	2	4
Total	50	100

Source: Survey data (2000)

4.2.5 Field abandonment and reasons for abandoning

The interviews showed that (38%) respondent household heads had recently abandoned fields while (62%) respondent household heads had not (Table 4.15).

Table 4.15: Distribution of field abandonment

Category	Frequency	Percentage proportions of the total respondents
Abandoned fields	19	38
Did not abandon fields	31	62

Source: Survey data (2000)

Reasons for abandoning fields mentioned by the respondents include soil fertility decline hence high input and lack of access to irrigation water supply (Table 4.16). Most of respondent (47%) abandoned their farms because the area is difficult to irrigate, especially in Ruaha Mbuyuni village.

Table 4.16: Reasons for abandoning

Reasons	Frequency	Percent proportions of people abandoned fields
Loss of fertility	4	21
Difficult to irrigate	9	47
Both	6	32
Total	19	100

Source: Survey data (2000)

4.2.6 Farmers efforts to take measures to improve soil fertility

Table 4.17 shows that all respondents are taking measures to improve soil fertility. All respondents do apply fertilizers in their fields, 42% apply fertilizer with other measures like crop rotation and crop residue while 58% apply only fertilizer. The results show that those people who apply fertilizer with other measures get good yields than those who apply only fertilizer.

Table 4.17: Measures taken to improve soil fertility

Measures taken	Frequency	Percent proportions of total respondents
Applying fertilizer only	29	58
Applying fertilizer and crop rotation	9	18
Applying fertilizer and crop residue	8	16
Applying fertilizer, crop rotation and residue	4	8
Total	50	100

Source: Survey data (2000)

4.2.7 The use of production inputs now and ten years ago

Table 4.18 shows that, the use of farm inputs (fertilizers and pesticides) have increased compared to ten years ago. The reasons mentioned were lose of soil fertility and climatic changes. This agrees with (Landon, 1991) that as the soil fertility of an area depreciate the production inputs increases. The Table shows that of the total 50 respondents 96% said that the production inputs has increased while only 4% said it has remained the same.

Table 4.18: The use of production inputs now compared to ten years ago

Use of inputs	Frequency	Percentage proportional of total respondents
Increased	48	96
Decreased	0	0
Same	2	4
Total	50	100

Source: Survey data (2000)

4.2.8 Farmer's perception of the changes in land resources

The survey showed that most of the farmers are aware of the land use changes and land resource degradation taking place in their area. Most farmers mentioned changes in climate as a very serious problem in their area, especially changes in

rainfall pattern, it was pointed out that about ten years ago rainfed agriculture was possible in their area but now it has been so difficult to cultivate without supplementing it with irrigation. Decline of soil fertility was also claimed to be a serious problem, once a new farm is opened good yield can be obtained without applying fertilizers but after two to three years fertilizers has to start being applied and the amount of fertilizer increases as the farm becomes old. The survey also showed that most of the respondents know how to detect soil fertility decline. This is based on their interpretation of indicators regarding crop condition. Indicators of soil fertility decline mentioned include decrease in crop yields and stunted crop growth (Table 4.19). Dejene *et al.* (1997) found that most farmers in Kondoa district were aware of soil degradation taking place on their farms and surrounding areas. It is not wise to neglect this wealth of indigenous knowledge.

Farmers also claimed of decreasing of fish production in the rivers, though no reason was mentioned, but the reason might be due to irrigation activities taking place in the area. According to Altiel, (1991), irrigation may influence aquatic animals as water returns to the streams after irrigation is often of poorer quality than the original water, and may cause death of plants and animals. Also return flows can carry sediment or silt, which raises the beds of irrigation canals, changes the direction of canals, clogs drains, and fills the streambeds of reservoirs and lakes downstream.

Table 4.19: Perception of indicators of soil fertility decline.

Indicator	Frequency	Percentage proportions of the total respondents
Decline in crop yield	40	80
Stunted plant growth	8	16
No opinion	2	4
Total	50	100

Source: Survey data (2000)

4.3 Soil characterization

4.3.1 Soil physical properties

Table 4.20, shows the proportions of sand, silt and clay particles for all the fields (i.e Ilongo, Mhinzi, Kikwale, Kiganboni and Madela,) of the topsoil and subsoil at depth of 0-30cm, 30-60cm and corresponding textural classes. It also shows the bulk densities at the same depth.

4.3.1.1 Soil texture

The textural class of the composite soil samples for Ilongo field, showed that the topsoil was sandy clay loam and that of Mhinzi field was sand loam. The subsoil was clay for Ilongo field and that of Mhinzi ranged from sandy loam to sandy clay loam. Generally, the percentage of sand in Mhinzi field is high in the topsoil and subsoil with mean values of 64.5% and 61% respectively compared to that of Ilongo with mean values of 55.5% and 39.25 respectively (Table 4.20). Although onions and paddy rice grows in a wide range of soils, clayey loam soils provide the best rooting medium for these crops (ILACO, 1981).

Table 4.20 Soil physical properties

Field	Site	Dept (cm)	Clay (%)	Silt (%)	Sand (%)	Text. Class	Bulk density G/cm ³
Ilongo	IL ₁	0 – 30	33.5	13	53.5	SCL	1.335
		30 – 60	52	9.5	38.5	C	1.300
	IL ₂	0 – 30	28	14.5	57.5	SCL	1.380
		30 – 60	48	12	40	C	1.325
Mhinzi	MH1	0 – 30	18	17	65	SL	1.435
		30 – 60	14	25	61	SL	1.310
	MH2	0 – 30	16	20	64	SL	1.415
		30 – 60	25	14	61	SCL	1.375
Kikwale	KK1	0 – 30	12.5	13.5	74	SL	1.445
		30 – 60	3	4.5	92.5	S	1.515
	KK2	0 – 30	12	15	73	SL	1.405
		30 – 60	9	11.5	79.5	LS	1.495
Madera	MD1	0 – 30	9.5	8	82.5	LS	1.480
		30 – 60	10	13.5	76.5	SL	1.405
	MD2	0 – 30	13	13	74	SL	1.385
		30 – 60	8	15	77	LS	1.395
Kigamb oni	KG1	0 – 30	25.5	14	6.5	SCL	1.315
		30 – 60	38	21.5	40.5	CL	1.280
	KG2	0 – 30	27	18	55	SCL	1.370
		30 – 60	42	18.5	39.5	C	1.210

Source: Survey data (2000)

The mean values of clay content of the topsoil for Ilongo and Mhinzi fields were 30.75% and 17% respectively, and that of subsoil were 50% and 19.5% respectively (Table 4.20). The clay content for Mhinzi field were within the acceptable range of 7 to 27% and suggested to be very good for most agricultural uses (Landon, 1984), but the high content of sand limits its use for onions and rice. The clay content for Ilongo field was slightly above the acceptable range and showing behaviour of poor aeration, drainage and restricted plant root growth. Therefore they require extra management efforts such as improved drainage and deep ploughing to minimize yield losses of the crops (Yates, 1977). The relative high clay content in the subsoil (mean value of 50%) for Ilongo fields shows the tendency of retaining water for a

long period thus, preventing them from rapid drying a condition which is favourable for rice and onions production. Yoshida (1978) also indicated that sandy soils with heavier subsoil are generally more productive for rice and onions than those soils that are sand throughout.

The soil textural class of the topsoil for Kikwale and Madela fields were sandy loam while that of subsoil ranged from loam sand to sand and loam sand to sand loam respectively. The soils in Kikwale and Madela fields has very high sand content with mean values of 73.5 and 78.25 for the topsoil respectively while that of subsoil were 82 and 76.75% respectively (Table 4.20). According to Landon, (1984) this soil is not suitable for most crops especially onions and rice as can not retain enough water. No paddy is grown in Msosa village, people grows maize, groundnuts, onions and beans and this can be the reason as to why people do not grow rice in Msosa. According to Landon (1984) this soil is also not suitable for onions but because of land scarcity people grow onions with high input in terms of fertilizer.

The textural class of the topsoil for soils in Kigamboni field was sandy clay loam while that of subsoil ranged from sandy clay to clay. The soils have clay content with mean values of 26.25% and 40% (Table 4.20) for the topsoil and subsoil respectively and according to Landon (1984), this soil is suitable for onions. The only problem with this area is that, it is not easily irrigable by using traditional canals as the water level is very low, but people with money uses small pumps to irrigate their farms and recently cultivation has expanded to the extent that all the land suitable for agriculture is almost finished (Land use map 1999).

4.3.1.2 Soil bulk density

The mean bulk density of the topsoil varied in the order of Madela (1.432g/cm^3), Kikwale and Mhinzi (1.425g/cm^3), Ilongo (1.357g/cm^3), Kigamboni(1.342g/cm^3) while that of subsoil varied in the order Madera, Kikwale, Mhinzi, Ilongo, Kigamboni, and showed the tendency of increasing gradually with increasing sand content (Table 4.20). However, this range of bulk density is rated as medium (Landon, 1991) and easily penetrable by roots. Results also showed that soils of Madela and Kikwale which have high percentages of sand had the highest bulk density while soils of Ilongo and Kigamboni which are dominated by clay had lowest bulk density. The increase of bulk density with increasing sand content is explained by high particle mass of the sand soils and lower organic matter.

4.3.2 Soil chemical properties

Table 4.21 shows the results of exchangeable cations, cation exchange capacity, and organic matter content for all the fields (i.e Ilongo, Mhinzi, Kikwale, Madera and Kigamboni) at depth of 0-30 and 30-60cm. It also shows the total N, soil pH and available P at the same depth.

Table 4.21: Soil chemical properties for Ilongo, Mhinzi, Kikwale, Madela and Kigamboni fields.

Field	Site	Dept (cm)	Exch. Bases (cmol(+)/kg)				CEC	% TN	% OM	Avail P. (ppm)	PH (1:2.5) H ₂ O
			Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺					
Ilongo	IL ₁	0 – 30	3.45	1.00	0.79	0.47	10.51	0.32	1.48	14.65	6.2
		30 – 60	3.5	0.9	0.24	0.34	5.3	0.29	1.25	6.9	6.0
	IL ₂	0 – 30	3.5	1.92	0.71	0.35	11.51	0.43	1.99	11.8	6.56
		30 – 60	3.6	1.53	0.28	0.34	3.8	0.29	1.44	6.25	6.2
Mhinzi	MH ₁	0 – 30	0.4	0.7	0.21	0.11	10.5	0.11	1.63	11.4	5.79
		30 – 60	0.35	0.56	0.17	0.08	9.4	0.06	1.33	7.6	5.56
	MH ₂	0 – 30	0.28	0.76	0.20	0.08	7.3	0.23	1.50	8.9	5.54
		30 – 60	0.24	0.63	0.18	0.07	9.8	0.17	1.82	5.95	5.43
Kikwale	KK ₁	0 – 30	0.21	0.5	0.2	0.09	7.75	0.18	1.14	9.15	5.85
		30 – 60	0.25	0.42	0.14	0.06	7.55	0.14	0.95	6.4	6.2
	KK ₂	0 – 30	0.31	0.47	0.2	0.06	7.85	0.15	1.15	6.3	6.32
		30 – 60	0.21	0.33	0.22	0.08	7.20	0.13	0.77	6.25	5.85
Madera	MD ₁	0 – 30	0.23	0.35	0.31	0.1	6.9	0.1	1.59	7.4	6.25
		30 – 60	0.28	0.26	0.23	0.09	9.5	0.06	0.54	6.1	6.56
	MD ₂	0 – 30	0.19	0.39	0.21	0.11	9.8	0.11	1.40	7.4	5.74
		30 – 60	0.18	0.29	0.13	0.07	7.3	0.05	1.15	4.95	5.53
Kigamb oni	KG ₁	0 – 30	2.7	1.19	0.73	0.59	11.91	0.31	1.71	11.25	6.35
		30 – 60	2.5	0.82	0.22	0.33	4.5	0.19	1.11	8.25	6.35
	KG ₂	0 – 30	1.7	1.64	0.71	0.44	12.81	0.36	1.74	10.4	6.55
		30 – 60	1.65	0.99	0.3	0.34	3.0	0.17	1.21	6.9	6.35

Source: Soil survey data (2000)

4.3.2.1 Organic matter, total nitrogen and available phosphorous

All fields contained low organic matter content. The organic matter content of the topsoil (0-30cm) ranged from 0.83 to 1.745 and according to Landon, (1991), this

value is rated as low to very low. The mean values in the topsoil were in the order of Ilongo (1.735%), Kigamboni (1.725%), Mhinzi (1.565%), Madela (1.495%), Kikwale (1.145%), (Tables 4.21). In all the fields organic matter content was found to decrease with increase of soil depth, a behaviour of alluvial soils (FAO, 1988) and showed a trend of increasing with the increase of clay proportions. Dutatre et al. (1993) observed the same trend of organic matter with clay variation. High temperature and good aeration of the topsoil could account for the low organic matter content in the soil because of enhanced rate of organic matter decomposition. The removal of rice and maize straw from the fields after harvesting for roofing may also be responsible for low organic matter recycling in the soil of the area. Soils with low organic matter may not be good for irrigation because organic matter influences soil structural stability which has big influence on water holding capacity. Water enters and moves through different types of soil structure at varying rates. The structureless soils allow water to percolate too rapidly or too slowly (Maletic and Hutchings, 1969).

The values of the total nitrogen in the topsoil ranged from medium to very low. They ranged from 0.105 to 0.375% in the topsoil and from 0.055 to 0.29 in the subsoil (Table 4.21). The mean values of the total nitrogen in the topsoil were in the order of Ilongo (0.375%), Kigamboni (0.375%), Mhinzi (0.375%), Kikwale (0.375%), Madela (0.375%). The mean values of total nitrogen in Ilongo and Kigamboni fields ranged from 0.257 to 0.297% which was ranked by Ponnampereuma (1972) as medium for crop growth, while that of Mhinzi, Kikwale and Madela fields ranged from 0.08 to 0.15% and ranked as low to very low. Since total N is known to be the

most important nutrient for crop yield (Yoshida, 1981) and crops requires relatively high amount of the nutrient, the total N in these soils is not adequate for optimum crop growth.

The mean value of available P in topsoil was in the order of Ilongo (13.225ppm), Kigamboni (10.825ppm), Mhinzi (10.15ppm), Kikwale (7.725ppm), Madela (7.40ppm) (Table 4.21). Following FAO (1983) and Dudal (1979) categorisation with respect to available P, these soils are ranged as medium to low in available P. The trend of available P within and across the fields was almost similar to that of organic matter, thus suggesting that soil organic matter supply is the main portion of available P in these soils. The low level of phosphorous in the subsoil indicated that the parent material is not rich in phosphorus, therefore, the use of phosphorus fertilizer might produce good response. Generally these soils are rated as unfertile soils and this has also been observed during interview as many respondents claimed of low soil fertility hence high inputs in term of fertilizer.

4.3.2.2 Soil pH

All soils had pH (1:2.5 H₂O) values greater than 5.1 and less than 7.0 (Table 4.21). The pH values of topsoil and subsoil varied from strongly acidic to very slightly acidic in all the fields. Ilongo and Kigamboni fields had relatively high soil pH (mean 6.38 and 6.45 respectively) in the topsoil and (mean 6.1 and 6.35 respectively) in the subsoil as compared to Kikwale, Madera and Mhinzi fields. The relatively low pH values in these fields may be due to acidification resulting from continuous application of ammonium based fertilizers which have acidifying effects. The soil pH

for all the fields observed to decrease with soil depth. However, the pH values were found to be within the acceptable range for many crop production (FAO, 1985). Also soils with these values of pH are considered to be suitable for irrigation as the values for satisfactory irrigated cropping are considered to be in the range of 5.1 to 8.5 (Maletic and Hutchings, 1969)

4.3.2.3 Exchangeable Ca, Mg, Na and K

The topsoil had low content of exchangeable Ca which was in the order of Ilongo (3.475 cmol(+)/kg), Kigamboni (2.2 cmol(+)/kg), Mhinzi (0.34 cmol(+)/kg), Kikwale (0.26 cmol(+)/kg), Madela (0.21 cmol(+)/kg) (Table 4.21). These values are rated as low level (Landon, 1991). There was a general trend that exchangeable Ca decreased with increase in soil depth except for Ilongo field. The observed high concentration of exchangeable Ca in Ilongo and Kigamboni was due to high clay content. These values seem to be suitable for irrigation activities as can not cause salinity problem if the irrigation water has no high concentration of salts (Landon, 1991).

The mean values of exchangeable magnesium (Mg) for the topsoil were in the order of Ilongo (1.46 cmol(+)/kg), Kigamboni (1.415 cmol(+)/kg), Mhinzi (0.73 cmol(+)/kg), Kikwale (0.49 cmol(+)/kg), Madela (0.37 cmol(+)/kg) (Table 4.21). These values are rated as medium to low level. The values observed to decrease with increase soil depth for all the fields. These values are also suitable for irrigation activities as can not cause salinity problem (Landon, 1991).

Exchangeable sodium (Na) in the topsoil were in the order of Kigamboni (0.75 cmol(+)/kg), Ilongo (0.72 cmol(+)/kg), Madera (0.26 cmol(+)/kg), Mhinzi (0.205 cmol(+)/kg), Kikwale (0.200 cmol(+)/kg) (Table 4.21). These values are rated as high to low level (Landon, 1991). Ilongo and Kigamboni fields has relatively high values of exchangeable Na and this indicated that, salinity and/or sodium toxicity is likely to be a limiting factor for crop production in these areas. However, these values of Na may not be good for irrigation as can cause soil sodicity which leads to soil compaction hence poor water infiltration and poor root penetration, but will depend on the chemical composition of irrigation water.

Exchangeable potassium (K) in the topsoil were in the order of Kigamboni (0.515 cmol(+)/kg), Ilongo (0.41 cmol(+)/kg), Madera (0.105 cmol(+)/kg), Mhinzi (0.095 cmol(+)/kg), Kikwale (0.075 cmol(+)/kg) (Table 4.21). These values are rated as low level (Landon, 1991). The relatively high values of exchangeable potassium (K) in Ilongo and Kigamboni fields was also due to high clay content.

Generally, the relatively low exchange cations were observed in Mhinzi, Kikwale and Madela fields indicating the relatively low fertility for these fields. These fields has high percentage of sand (> 61%) (Table 4.21) which has low ionic holding capacity. Plant nutrients in these soils can easily be leached by rain or irrigated water. Malhi et al., (1994) observed the same trend of exchangeable cation with soil texture and reported that coarse soils are more susceptible for exchangeable bases to be washed away by water during rainfall or irrigation.

4.3.2.4 Cation Exchange Capacity (CEC)

The mean cation exchange capacity of the topsoil and subsoil were Ilongo (11.0 and 14.55 cmol(+)/kg), Mhinzi (8.9 and 9.6 cmol(+)/kg), Kikwale (7.8 and 7.375 cmol(+)/kg), Madera (8.35 and 8.4 cmol(+)/kg), Kigamboni (12.35 and 13.75 cmol(+)/kg) respectively (Table 4.21). The observed range of cation exchange capacity in the topsoil for Ilongo and Kigamboni (11-14.55 cmol(+)/kg), were rated as medium while that of Mhinzi, Kikwale and Madera (7.8 – 8.9 cmol(+)/kg), were rated as low level (Landon, 1991). This rating implies that the ability of exchangeable cations of the studied soils to neutralise negative charge of the soil was at low level. The comparatively high cation exchange capacity of Ilongo and Kigamboni in the topsoil was due to relatively high amount of clay and organic matter. However these soils are considered to be suitable for irrigation as the minimum values for satisfactory irrigated cropping are considered to be 3meq 100/g soil in the upper 30cm for rice and 4meq 100/g for other arable crops (Dent and Young, 1981).

Generally, soils in the study area are considered to be suitable for irrigation activities though in some places extra management is required. For example soils in Kikwale and Madera fields has been observed to have high percentage of sand, these soils require extra management as they may have low waterholding capacity. The common specific limitations to crop productivity were low organic matter content, low total available nitrogen, low exchangeable cations and low cation exchange capacity. However pH values and bulk density were observed to be within the acceptable range.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions can be drawn from this study:

Seven main land use classes namely cultivated area (irrigated and rainfed fields), riverine vegetation, forest, woodland, scrub, settlement and abandoned field were observed in the study area. Between the year 1955 to 1999 the area under traditional irrigation activities increased from 488ha to 4130.7ha with expansion rate of 82.79ha/year.

Irrigation activities have been observed to be the most and influential activities responsible for land use changes. It has also been observed to influence settlement which has expansion rate of 25ha/year and has also increased the extent of socio-economic activities as people settled for irrigation purposes requires fuelwood and charcoal as sources of energy and trees for building houses.

Land use changes was mainly observed along the Great Ruaha River and its tributaries (Lukosi, Msosa, and Mwega rivers) where there is good land and water availability favoured irrigation activities.

The soils in the study area are mostly sand to clay and are moderate to well drained. The soil type and fertility has also been observed to be responsible for land use changes as more people tend to cultivate more in areas with good soils and more fertile.

5.2 Recommendations

Based on technical and socio-economic findings obtained in this study, the following recommendations can be made in order to enhance sustainable use of land resources.

The removal of maize and rice straw from the field after harvest should be minimised as these can improve soil organic matter. Also, NPK fertiliser should be applied to supplement the deficiency of available phosphorus and total nitrogen. Also the use of farmyard manure should be encouraged.

Drainage network should be improved in order to minimize the problems of salinization and return flow in the river which may affect aquatic animals.

Further research on land resource degradation due to irrigation activities taking place in the area is highly recommended in order to obtain sustainable use of the available land resources.

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APPENDICES

Appendix A: A sample of household questionnaire

SECTION A: Background Information

- A1. Gender of household head:
 - A2. Date of birth:
 - A3. Place of birth:
 - A4. Tribe
 - A5. Place of usual residence
 - A6. Years spent in this village
 - A7. Did you shift into this village?
 - A8. If yes, give reason for shifting
 - A9. Highest level of education:
 - A10. Marital status
 - A11. How many dependants do you have?
-

SECTION B: Employment & Cash income

- B1. What is your main occupation:
 - B2(a). If B1 is cultivation, what type of crops do you usually grow ?
 - B2(b) How much yield (kg) did you get during last season as mentioned in Q B2(a)?
 - B2c. What area per crop do you grow?
 - B3. What is the amount used for subsistence?
 - B4. What is the amount sold?
 - B5. What is the price obtained (sh/kg) ?
 - B6. What is the total benefit accrued?
 - B7. Where do sells take place?: (a) at the field (b) at home (c) at the market.
 - B8. From B2 (a), mention field operations you have undertaken: (a) land clearing, (b) tillage operations, (c) weeding, (d) fertiliser, and (e) harvesting.
 - B9. If B1 is charcoal/lime making, carpentry, pottery, gathering firewood, where do you get raw materials ?
-

SECTION C: Assets & Expenditure

- C1. Do you own this house or rent it?
 - C2. What are the materials used to build your house ?
 - C3. How do you rank wealth in your area?
 - C4. What are the sources of energy for the following? (a) Cooking, and (b) Lighting:
 - C5. If it is wood or charcoal: where do you normally get it ?
-

SECTION D: Land tenure and land use

- D1. Does your household own land for agricultural use ?
 - D2. If D1 is yes, have you purchased, rented, or inherited ?
 - D3. For how long have you owned the land?
 - D4. How large is your land area (acres) ?
 - D5. How many acres do you cultivate every season?
 - D6. For how long have you been cultivating those acres?
 - D7. Have you abandoned any farm? If yes why?
 - D8. Do you keep any livestock? If yes, what type and quantity?
 - D9. Do you access any extension services?
 - D11. Is your land/farm adequate? If not what are your plans?
 - D12. Are you planning to change the present land use? If yes, what kind of land use do you envisage and why?
-

SECTION E: Soil conservation and reasons for lowering productivity

- E1. Do you experience soil erosion on your land/farm?
- E2. If E1 is yes, what kind of erosion? Water, wind, others (specify).
- E3. Do you practice land husbandry?
- E4. Which type of soil conservation measure do you practice?
- E5. Are there any constraints to soil conservation? Explain
- E6. What are the major causes of lowering of agricultural production in your cultivating area ?
- E7. How do you compare the use of production inputs now and ten years ago? And give the reasons for those changes.

E8. Do you engage yourself in irrigation activities?

E9. Which type of irrigation?

E10. Do you find any difficulties in doing irrigation agriculture?

E11. Where do you get water for irrigation?

E12. How many hectares do you irrigate every year?

E13. Do you think irrigation has influence on your production?

E14. Do you think irrigation can lead to land degradation? If yes explain how.

Appendix 2: Guide to general evaluation of some soil chemical and physical properties

Table 3.1: Rating for bulk density and consistency

Rating	Bulk density (g/cm ³)	Consistency when moist
Easy	< 1.2	Loose, very friable
Moderate	1.2 – 1.4	Friable, firm
Difficulty	1.4 – 1.8	Very firm
Very difficulty	> 1.8	Extremely firm

Source: Landon, (1991)

Table 3.2 Rating for cation exchange capacity and percentage base saturation

Rating	CEC	PBS
High	> 20	> 50
Moderate	20 – 12	50 – 25
Low	12 – 4	25 – 15
Extremely low	< 4	< 15

Source Landon, (1991)

Table 3.3: Rating for Exchangeable Ca, Na and Mg

Rating	Exch. Ca ⁺⁺	Exch. Mg ⁺⁺	Exch. Na ⁺
Very high	> 20	> 8	> 2.0
High	20 – 10	8 – 3	2.0 – 0.7
Medium	10 – 5	3 – 1.5	0.7 – 0.2
Low	5 – 2	1.5 – 0.5	0.2 – 0.1
Very low	< 2	< 0.5	< 0.1

Source: Landon, (1991)

Table 3.4: Rating for available nitrogen, phosphorus and organic matter content

Rating	OM (%)	Total N (%)	Avail. P (ppm)
Rich	> 6.0	> 0.5	> 21
Adequate	6.0 – 4.3	0.5 – 0.2	21 – 12
Marginal	4.2 – 2.2	0.2 – 0.1	12 – 5
Deficiency	< 2.0	< 0.1	< 5

Source: FAO (1983) and Dudal (1979).

Table 3.5: Rating for pH values at soil: water ratio

Rating	PH (1:2.5 H ₂ O)
Extremely acidic	> 4.5
Very strongly acidic	4.5 – 5.0
Strongly acidic	5.1 – 5.5
Medium acidic	5.6 – 6.0
Slightly acidic	6.1 – 6.5
Very slightly acidic	6.6 – 6.9
Neutral	7.0
Very mildly alkaline	7.1 – 7.3
Mildly alkaline	7.4 – 7.8
Moderate alkaline	7.9 – 8.4
Strongly alkaline	8.5 – 9.0
Very strongly alkaline	> 9.0

Source ILACO (1991)

Appendix 3: Calculation of area transformed into irrigated field

Consider table 4.3 from 1955 to 1976

Rainfed to irrigated	= 238.9ha
Riverine vegetation to irrigated	= 1227.3ha
Scrub to irrigated	= 329.8ha
Settlement to irrigated	= 12.5ha
Woodland to irrigated	= 48.4ha
Total	= 1856.9ha

Percentage contributed by riverine vegetation = $1227.3/1856.9$
= 66%

Consider Table 4.4 from the year 1976 to 1999

Rainfed to irrigated	= 148ha
Riverine vegetation to irrigated	= 1372.5ha
Scrub to irrigated	= 374ha
Settlement to irrigated	= 3.3ha
Woodland to irrigate	= 337.8ha
Total	= 2235.6ha

Percentage contributed by riverine vegetation = $1372.5/2235.6$
= 61%