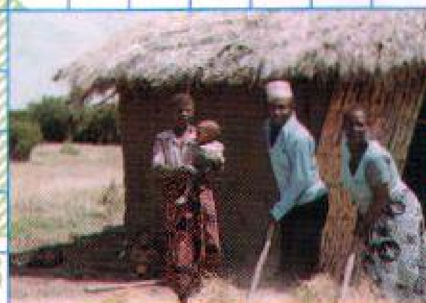
ltivation in the farming systems of Sukumaland, Tanzania

A quest for sustainable production under structural adjustment programmes



H.C.C. Meertens

PROPOSITIONS

1 An understanding of the dynamics of agricultural production systems is necessary for developing relevant and acceptable policies and technologies aimed at improving the sustainability of the various land use systems in these production systems.
This dissertation

2 Technologies aiming to improve sustainability can lead to a reduction of labour productivity and eventually impoverishment of farm households if those technologies require high inputs of labour.
This dissertation

3 The adoption of Integrated Nutrient Management does not depend on the nutrient balance alone. It also requires active participation of farmers and additional information on ecology, economy, public policy, land-labour ratios of the farming systems, and farm household strategies.
This dissertation

4 Integrated Nutrient Management approaches are not appropriate for farming systems in SSA characterized by relatively low land use intensity, low population density, low livestock density and/or poor market access.
This dissertation

5 Sustainable rice cultivation in Sukumaland on the basis of low external inputs requires a conducive economic and policy environment.
This dissertation

6 Structural adjustment programmes backed by IMF and World Bank in Tanzania incorrectly give priority to balanced government budgets over balanced household budgets and balanced soil nutrient budgets.
This dissertation

7 Farmer participation is a necessary condition for identifying agricultural constraints and possible solutions. However, without strong farmer organizations, participation is not sufficient to create the requirements for those solutions.

8 The use of the sustainability concept in the international agricultural debate is yet another example of how the West imposes its way of thinking upon the non-industrialized world.

9 Sustainable agricultural development in non-industrialized countries is helped more by reducing subsidies to farmers in industrialized countries, than to farmers in non-industrialized countries.

10 Government statements that political refugees can safely return to their countries sometimes give the impression that they are only based on the political situation near the embassies of the governments which make these statements.

11 The increasing popularity of environmental and wildlife organizations in the West could explain the decreased attention paid to the fight against hunger in the World.

12 African football players and athletes are better indicators of the potential of the African continent than reports and publications from organizations of the United Nations.

13 Professional cyclists are more amusing liars than politicians.

H.C.C. Meertens
Rice cultivation in the farming systems of Sukumaland, Tanzania.
A quest for sustainable production under structural adjustment programmes.
Wageningen, 7th September, 1999

Rice cultivation in the farming systems of Sukumaland, Tanzania

A quest for sustainable production under structural adjustment programmes

H.C.C. Meertens

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Rice cultivation in the farming systems of Sukumaland, Tanzania

A quest for sustainable production under structural adjustment programmes

H.C.C. Meertens

Proefschrift

ter verkrijging van de graad van doctor
op gezag van de rector magnificus,
van de Wageningen Universiteit,
dr. C. M. Karssen,
in het openbaar te verdedigen
op dinsdag 7 september 1999
des namiddags te vier uur in de Aula

This thesis is dedicated to my parents, who always left me free in my choices

Cover design and lay-out: Basislijn, Amsterdam
Production and distribution: Royal Tropical Institute, KIT, Postbus 95001, 1090 HA Amsterdam

Printed and bound in the Netherlands

ISBN 90 5808 092 7 (Wageningen Agricultural University)
ISBN 90 6832 130 7 (Royal Tropical Institute KIT Amsterdam)

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List of Abbreviations used

ARI	Agricultural Research Institute, Tanzania
ARTI	Agricultural Research and Training Institute, Tanzania
C	Carbon
CEC	Cation Exchange Capacity
CIMMYT	International Maize and Wheat Improvement Centre
DC	Developed Country
FAO	Food and Agriculture Organization of the United Nations
FSR	Farming Systems Research
FSRE	Farming Systems Research and Extension
FSRP	Farming Systems Research Project
GATT	General Agreement on Tariffs and Trade
HYV	High Yielding Variety
ICRA	International Course for development oriented Research in Agriculture
IMF	International Monetair Fund
INM	Integrated Nutrient Management
K	Potassium
KIT	Koninklijk Instituut voor de Tropen, Amsterdam
LDC	Less Developed Country
LEISA	Low External Input Sustainable Agriculture
LU	Livestock Unit
N	Nitrogen
NGO	Non-Governmental Organization
P	Phosphorus
PI	Productivity Index
RELO	Research-Extension Liaison Officer
RTI	Royal Tropical Institute, Amsterdam (=KIT)
SG2000	Sasakawa Global 2000
Si	Silicon
SSA	sub-Saharan Africa
T&V	Training and Visit (extension system)
TFC	Tanzania Fertilizer Company
TSP	Triple Super Phosphate
UNCED	United Nations Commission on Environment and Development
URT	United Republic of Tanzania
VCR	Value Cost Ratio
ZRTC	Zonal Research and Training Centre, Tanzania

Preface and acknowledgements

In 1992 I returned to the Netherlands after three years of field work in Sukumaland, Tanzania. The time for transferring all impressions and information from the field work onto paper had been too short due to the time-consuming on-farm activities. Back in the Netherlands the Royal Tropical Institute offered me an opportunity to sit and write more about Sukumaland. In those days several people asked me why I did not do this in the form of a thesis. My answer was that this would take too much time as I preferred to work soon again in a project.

In 1996 I returned to the Netherlands after another two and a half years of work in Tanzania. The former team leader of the Tanzania-Netherlands FSR Project Lake Zone, Driek Enserink, asked me if I was not interested in writing a thesis about rice cultivation in Sukumaland. Both my assignments in Tanzania included on-farm activities in Sukumaland rice fields and a compilation of these activities would be interesting. After the positive feedback from Niels Röling regarding the whole idea, and his acceptance of my request to act as my promotor, I decided to give it a try and to write the chapters of the thesis in the form of articles. In this way I would not have wasted the time of writing in case I was offered an interesting job halfway through the thesis. As time moved on I realized that I had to finish the thesis first before accepting a new assignment. The result is this thesis and the fact that I crossed the one hundred page barrier for the first time in my life!

A considerable amount of information in this thesis originates from on-farm activities conducted in the Tanzania-Netherlands FSR Project Lake Zone and the Kilimo/FAO Plant Nutrition Programme in Tanzania. I thank the Ministry of Agriculture & Co-operatives of the United Republic of Tanzania for allowing me to use this information for the purpose of obtaining a PhD. The interpretation of data and opinions expressed in this thesis are, however, my sole responsibility and do not necessarily reflect those of the Ministry of Agriculture & Co-operatives.

Due to the importance of the on-farm activities in Tanzania this thesis reflects also the energy and thoughts from many Tanzanians. In the first place I thank my former counterparts, Leonis Ndege and Peter Lupeja, with whom I worked together on a daily basis for several years. Due to their commitment, farmer orientation, practical knowledge and friendly attitude we were able to obtain useful field data. Leonis Ndege was further also kind enough to translate the summary into Swahili. In our field activities we were assisted by extensionists. Bernard Myatiro, James Petro, Samson Ibrahim, Regina Bamuhiga, John Lubango, F. Tadayo, Marekana Matina, Enos Kadiko, Rehema Abeid, Ronald Wesaka and Nyundo Kapachi are thanked for their good cooperation. Special thanks go to the farmers, who participated in the on-farm activities. I single out Makoye Dadi, who assisted us like an extension worker. Without the sense of responsibility and interest of the farmers the on-farm activities would have failed to deliver any valuable information. Further assistance has come from my former colleagues of the Tanzania/Netherlands FSR Project Lake Zone, especially Geophrey Kajiru, from the zonal director of Research and Training in the Lake Zone, Joe Kabissa, from the Regional Agriculture and Livestock Development Officer in Mwanza region, Mr. Sarakikya, and from the District Agriculture and Livestock Development Officer in Maswa district, Mr. Bori. All are thanked for their cooperative attitude.

My promotor, Niels Röling, is thanked for his contagious enthusiasm. There were several times that I was doubtful about the purpose of writing this thesis: each time the enthusiasm of my promotor pulled me through these doubts. I further highly appreciate his advice on the main aspects and literature sources, his open-minded supervision, and his pleasant association with me.

My co-promotor, Joost Brouwer, is thanked for his broad and pleasant support. For each aspect of writing a thesis he supplied me with advice. I very much appreciate his devotion to supervising me, his sincere interest in the thesis subject, his accurate comments and his attempts to upgrade my written English.

Many other people contributed in one way or another to the writing of this thesis. I take the opportunity to mention here those people who contributed in a considerable way. First of all I like to mention Driek Enserink, who as already mentioned was the real initiator of this enterprise. Also during the writing and publishing he continued to supply me with suggestions, advice and assistance. I thank him for his never-ending encouragement and belief in my capabilities. Yves Gillet, the former CTA of the Kilimo/FAO Plant Nutrition Programme in Tanzania, and Rabindra Roy at the FAO headquarters in Rome were very helpful with supplying reports and documents. Willem Heemskerk, Joseph Makoye, Simon Jasperse, André de Jager and Klaas Tamminga assisted me whenever I requested certain publications or unpublished documents. All are thanked for their assistance in this literature retrieval.

Some important foundations of this thesis were laid during very interesting scientific discussions with Louise Fresco and Willem Stoop. I thank them for sharing their views and literature sources with me. The thesis improved also from the comments which were made by Niek Koning on structural adjustment in Tanzania and by Bert Janssen on rainfed rice nutrient balances. I thank them for their time and willingness to give these remarks. Niek Koning supplied me further with interesting literature on population growth and economic development.

The owners of the Free Press, Simon & Schuster Inc., the Johns Hopkins University Press, the IFO Institute for Economic Research and the Cambridge University Press are thanked for their permission to reproduce previously published material in this thesis. Titia Hajonides is thanked for her assistance in drawing some of the maps and Petra Penninkhoff for improving one of the data presentations.

Writing this thesis would not have been possible without the understanding, support and love from my wife Elizabeth. Asante sana!

1 Introduction

Planning for sustainable agricultural development

Sustainable development is at present the dominant paradigm guiding development planning, and no sector other than agriculture has a greater role in moving towards development that is sustainable (Smith and McDonald, 1998). Due to the wide range of definitions for sustainable agricultural development there is, however, considerable confusion about its characteristics. Most definitions of sustainable agriculture do contain these three important criteria:

- environmental quality and ecological soundness
- plant and animal productivity
- socio-economic viability

A system must be ecologically sustainable or it cannot persist over the long term, and thus cannot remain productive and profitable. Likewise, a system must be productive and profitable over the long term or it cannot be sustained economically, no matter how ecologically sound it is (Smith and McDonald, 1998). For assessing the sustainability of agriculture at the planning stage it is thus necessary to look at biophysical, and economic as well as social indicators. Such assessments have to be made at the field, farm, watershed and region/nation scales. Figure 1.1 shows that different types of sustainability indicators are dominant at different scales. Stakeholders tied to certain scales will thus have different views of sustainable agriculture. For farming households and regional/national policy makers socio-economic factors predominate while for conservationists and agricultural researchers biophysical factors predominate. For resource-poor farmers sustainable livelihoods come before sustainable environments and this can be a source of conflict with conservationists (Low, 1993). A different view is that sustainability is the emergent property of a soft system, i.e. the result of collective action based on shared common perspectives and negotiated agreement on a common goal, on self-restraint and on contribution to collective effort (Bawden and Packam, 1991).

Outlook for sustainable agricultural development in sub-Saharan Africa/Tanzania

Most of sub-Saharan Africa (SSA) presently experiences enormous population growth accompanied by rather slow or marginal growth in agriculture. Statistics from FAO show that annual per capita food production has been declining without interruption in this part of the world since 1970. Although this decline has lessened in recent years, the daily dietary energy supplies per capita in SSA remain insufficient. The number of chronically undernourished people in SSA has more than doubled from 96 million in 1970 to over 200 million in 1995 (FAO, 1997). Specific data for Tanzania[1] show that for this country the per capita food production actually increased in the 1970s, stabilized in the 1980s and started to decline in the 1990s. From a national point of view this is obviously not sustainable agricultural development.

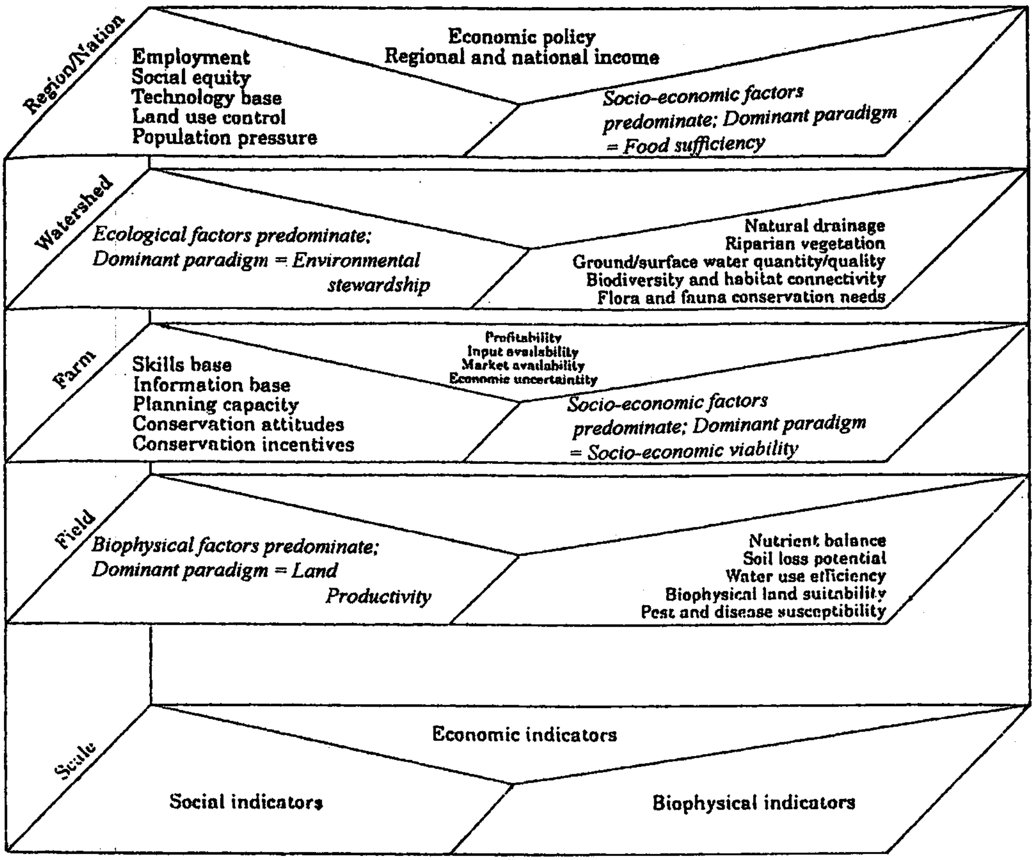
In the 1970s attempts were made to increase agricultural production in SSA in a quick way to reverse the trend of declining per capita food productions. The followed strategy was a duplication of the Green Revolution, which had been successful in some parts of Asia. This strategy is based on the adoption of a package of agricultural inputs like high-yielding varieties, mineral fertilizers, herbicides and pesticides. However, this capital-intensive method did not succeed in the predominantly pre-commercialized, sparsely populated and/or semi-arid parts occupying most of SSA.

According to Cleaver (1993), the slow intensification of agriculture in SSA was caused by weak agricultural research and extension, poor state of roads, telecommunications and posts, considerable decline in rainfall, government control frustrating the farmers, and ill-conceived public agricultural projects. The structural adjustment programmes which started in the 1980s saw macro-economic distortions in SSA-countries as the main obstruction to agricultural growth and economic growth in general. Many SSA-countries had neglected their agricultural sector for a long time, and had provided their urban populations with cheap food at the expense of production incentives for farmers (Borlaug and Dowswell, 1995). A key element in adjustment programmes is a reduction of the taxation of farmers by liberalizing pricing and marketing of agricultural products and by reducing the protection of industry (World Bank, 1994). Through liberalized markets and private traders the agricultural sector is expected to improve, and a much needed intensification of agriculture can take place via higher consumption rates of inputs like mineral fertilizers, herbicides and pesticides. In contrast to the Green Revolution attempts of the 1970s, the structural adjustment programmes do not regard government subsidies of agricultural inputs an efficient strategy for agricultural intensification in SSA. Even more important deterrents to fertilizer use in SSA than prices have been supply shortages and inefficient distribution systems due to extensive government interventions (World Bank, 1994). According to Cleaver (1993) scarce public funds can better be allocated to improving roads, strengthening distribution networks and/or training farmers than to providing subsidies to farmers for the use of inputs.

Liberalization of international agricultural trade was expected to raise world market prices of agricultural products, and increase outlets for farmers in less developed countries (LDCs) such as SSA-countries, by ending the dumping policies of developed countries (DCs) and increasing access to DC markets. However, the GATT Uruguay Round agreements gave LDCs only a limited increase in access to DC markets, and hardly restricted the dumping of agricultural products by DCs (Koning et al., 1997). In 1990 agricultural production costs in DCs were lower than in LDCs, and this perhaps explains why food imports by LDCs are actually increasing and have made them net importers of food (Bairoch, 1997). Farmers in LDCs cannot compete with farmers in DCs, and this lack of market opportunities in combination with low purchasing power of consumers in LDCs and low agricultural prices pose major bottlenecks to LDC food security. The so called liberalization of international agricultural trade is thus so far an advantage for DCs, and prevents the development of local food production in LDCs (Röling et al., 1998).

Due to high population growth in the past decades most parts of SSA are now, according to Cleaver (1993), so densely populated that there is a need and stimulus for agricultural intensification. Others, however, regard the sharp increase in population densities as a main contributor to increased deforestation, desertification and soil erosion (FAO, 1991). A rather hidden reason for the slow agricultural growth in

Figure 1.1
Sustainability indicator groups useful in agricultural sustainability assessment at four scales



Source: Smith and McDonald (1998)

regard to the high population growth is thought to be the gradual process of soil nutrient depletion in many parts of SSA (Smaling, 1993). An assessment of the rate of major nutrients depletion under agriculture for 35 crops in 38 SSA-countries revealed generally negative budgets for nitrogen, phosphorus and potassium (Stoorvogel and Smaling, 1990). An Integrated Nutrient Management (INM) strategy, which combines the use of locally available resources and external inputs, and includes management practices that save nutrients from being lost from the system and interventions that add nutrients from outside, is advocated to increase production and develop sustainable agriculture in SSA (Smaling et al., 1996).

Within the Low External Input and Sustainable Agriculture (LEISA) policy, INM methods are one of the important strategies. The LEISA approach is aimed at making optimal use of local available resources and only limited use of external inputs in a most efficient way (Kieft, 1992). For soil fertility management low inputs of mineral fertilizers have to be combined with applications of farmyard manure and where applicable the use of green manures, compost, agroforestry and erosion control. The result should be a sustainable increased production. Data from some 63 sustainable agriculture projects and programmes from all over the world have been gathered to demonstrate that the LEISA approach is capable of increasing food production while at the same time environmental degradation and dependency on external resources are reduced (Pretty et al., 1996).

Research problem and objective of this thesis

Pretty (1995), as one of the advocates of sustainable agricultural development on the basis of LEISA, states that the principal barrier to INM and LEISA is the absence of a favourable policy environment, due to continuous preference of governments, donors, and international agricultural institutes for external inputs and technologies in their strategies for sustainable agricultural development. Farm households on the other hand have to supply greater inputs of labour and have to acquire new management skills and knowledge for the adoption of INM and LEISA in general. Pretty (1995) gives the impression that INM and LEISA can be adopted by farm households from all over the world whenever farmers invest in learning the new methods, and policy environments are favourable. The **research problem of this thesis** is:

Can farm households from SSA-countries adopt INM/LEISA for generating sustainable agricultural development in the context of liberalization of international agricultural trade, structural adjustment programmes, and severe population growth?

This thesis investigates options for sustainable agricultural development in a particular part of SSA. The selected area covers the Mwanza and Shinyanga regions in northwestern Tanzania, which are often collectively called Sukumaland due to the predominance of Wasukuma people in these two regions. Generally Sukumaland has a semi-arid climate and agriculture is hampered by unreliable and low rainfall. In the past fifty years the population density has doubled in most parts. This strong increase in population has triggered several important changes in the farming systems of these regions. One important change is a reduction of grasslands in the valleys through increased cultivation of rice.

Economic reform programmes backed by the international donor community and guided by the International Monetary Fund (IMF) and the World Bank started in Tanzania around 1986. These reform programmes are commonly known as structural adjustment programmes and have been implemented in almost every SSA-country from the early 1980s onwards. Structural adjustment programmes required drastic changes in the national economic policies of Tanzania and had great impact on the marketing of agricultural outputs and inputs.

In this thesis the rice cultivation systems in Sukumaland serve as a case study for investigating the importance of social, economic and biophysical sustainability indicators at the field, farm, watershed and regional/national level in the development of sustainable agriculture. The investigation concentrates on soil fertility management rather than water use efficiency or pest and disease susceptibility, due to its importance for sustainable rice cultivation in Sukumaland. The **objective of this thesis is:**

To explore if INM/LEISA approaches are capable of generating sustainable soil fertility management in the rice cultivation systems of Sukumaland, Tanzania, within the context of structural adjustment programmes.

The Sukumaland case study is subsequently compared to other parts of SSA and Asia in order to see whether conclusions regarding Sukumaland can be extrapolated with regard to the potential of INM and/or LEISA in developing sustainable agriculture under liberalized international agricultural trade, structural adjustment programmes, and strong population growth. For this comparison the entire farming systems of Sukumaland, of which the rice cultivation systems are a part, need to be analysed.

Outline of the thesis

The current effects of structural adjustment programmes on agricultural development in Tanzania are discussed in *Chapter 2*. The current performance of agriculture is compared to the pre-reform and post-independence periods. Trends in per capita production of major food and cash crops are compared with trends in availability and consumption of mineral fertilizers.

A general description of the overall farming systems in Sukumaland and their dynamics is supplied in *Chapter 3*. In addition to climate, soils and vegetation, this description also includes a historic overview. Changes in agricultural practices are presented and analysed according to alterations in population density, ecology, technology, economy and public policy.

Chapter 4 presents a detailed description of the rice cultivation systems in Sukumaland. The indigenous system of water harvesting is explained, as well as methods of land preparation, rice planting, selection of cultivars, weeding and harvesting. Differences in cultivation management practices are explained according to variations in soils, climate, population density and household characteristics. The performance of the rice cultivation systems is analysed and compared with the main constraints perceived by the farmers.

One of the constraints mentioned by the farmers was a decline in rice yields. This decline was thought to be related to a decrease in soil fertility. *Chapter 5* presents the results of subsequent on-farm soil fertility research in the Mwanza and Shinyanga regions. The application of a low dose of urea (30 kg N ha^{-1}) at tillering was tested under varying conditions in these two regions and was found appropriate for recommendation in entire Sukumaland.

Chapter 6 deals with the constraints to adoption of the recommended urea-rice technology by farmers in Sukumaland. This chapter shows how structural adjustment programmes influenced the availability of mineral fertilizers such as urea, and the profitability of the urea-rice technology at the household level. The rate of adoption is also explained by the research approach followed, the performance of the extension service, and the characteristics of the rice cropping systems in Sukumaland.

The use of locally available resources such as kraal manure and rice husks, and the introduction of green manure and multipurpose trees as an alternative to urea for soil fertility management in the rice cropping systems of Sukumaland, are the subject of *Chapter 7*. This chapter also presents calculations of balances for nitrogen, phosphorus and potassium for the cultivation of rice in Sukumaland. The productivity of labour for soil fertility management systems based on locally available resources is discussed because of its importance with regard to adoption of such soil fertility management systems by farming households.

In *Chapter 8* the Sukumaland case study is compared with other parts of SSA and Asia to evaluate the potential of INM and/or LEISA for sustainable agriculture. This section starts with a description of soil fertility management according to the intensity of land use. An overview of factors which can determine shifts in soil fertility management follows. Labour productivity is further discussed because of its importance in relation to soil fertility management. The research problem of the thesis is discussed and the chapter ends with general conclusions about the potential of INM and/or LEISA for sustainable agriculture in SSA.

In *Chapter 9* the main findings of chapters 2 to 8 are summarized and discussed in connection with the objective of the thesis. Main conclusions with regard to the objective and some additional conclusions are drawn. The chapter ends with recommendations regarding policies to be followed in Sukumaland to reach sustainable rice cultivation and sustainable agriculture in general.

Notes

1 The FAO document *The State of Food and Agriculture 1997* included a computer diskette with time series data for about 150 countries, including Tanzania.

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Bert Meertens[1]

2 Rural development in Tanzania under Structural Adjustment Programmes: Is it really so positive?*

Abstract. This paper discusses the effects of structural adjustment programmes on agricultural development in Tanzania during 1986-96. The performances in the food and cash crop sectors and the availability and consumption of agricultural inputs during 1986-96 are compared with periods prior to IMF/World Bank backed reform. The positive developments in the first five years of reform appear to be not sustainable. Presently productivity levels per rural capita for important food and cash crops are declining. The removal of subsidies on agricultural inputs from 1991 onwards are crucial in explaining the decline in maize production, the main food crop in Tanzania. Some assumptions behind the reform measures are proving to be wrong. Modifications are thus needed to improve the agricultural sector of Tanzania in a sustainable way. Structural adjustment programmes usually go too far in reducing the role of the government. This paper states that government involvement might be necessary to ensure a higher consumption of agricultural inputs and thus a better performance of the agricultural sector in Tanzania.

Key words: Rural development, Structural adjustment, World Bank/IMF policies, Fertilizer consumption, Food security, Tanzania

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* Submitted to *Agriculture and Human Values*

Introduction

In the early 1980s Tanzania's economy was deteriorating with dazzling speed. The economic decline revealed itself in many ways. Real GDP was decreasing, agricultural growth was less than population growth, the government faced high fiscal deficits, inflation rates were high and increasing, industrial output declined 15 per cent annually and the country's transport system and other public services (health, education, research, extension) were worsening tremendously (Mans, 1994). The origins of this crisis were external as well as internal. In the 1970s Tanzania's economy was affected by quadrupling oil prices, severe droughts, the break-up of the East African Community and the war with Uganda under Idi Amin. After the Arusha Declaration in 1967 Tanzania followed a development strategy based on socialism, and government control on every aspect of life started to increase. The banking system was dominated by monopolized, inefficient state banks. Foreign exchange was controlled by the government and private holding of foreign currency was illegal.[1] Prices of 400 consumer goods were controlled by the government. Imports were restricted and import duty rates went up to 200 per cent with an additional sales tax of up to 300 per cent (Mans, 1994). The food market was controlled and food subsidies were supplied to an overstaffed and underpaid civil service. The marketing of export crops was dominated by a large number of inefficient parastatals and by government controlled cooperative unions. Foreign donors doubted the willingness of the Tanzanian government to address the internal origins of the economic decline and reduced their aid sharply after 1981. This led to declining imports of (industrial) spare parts which could no longer support the economy and of consumer goods which caused widespread shortages (Mans, 1994).

In 1981 the World Bank started its argument for structural adjustment in Africa with the publication of the so called Berg Report. This report was a response to the worsening situation in Africa in the 1970s, which was characterized by almost no growth in average incomes over the decade, and an actual decline in per capita food production. The World Bank offered help, but only to individual African governments which were prepared to adjust to the requirements of the international financial institutions (Barratt Brown, 1995). Tanzania was one of those countries to which the World Bank and the International Monetary Fund (IMF) offered help in the form of restructuring in the early 1980s. The Tanzanian leaders did not accept the conditions for help although they agreed that they had to change their policies. In 1981 the government launched the National Economic Survival Programme (NESP) which aimed at increasing national production and exports. This was followed by a structural adjustment programme between 1982 and 1985. The main aim of this programme was to prune the central government budget by restructuring several public enterprises (Mbonile, 1995). In addition it was a reduction of government control on the food market. The reform measures had, however, limited impact on the macroeconomic imbalances and were not backed by the donor community, primarily because of inappropriate exchange-rate policies (Mans, 1994). At the end of 1985 Mwinyi followed Nyerere as President of Tanzania and at this time the government's resistance to economic reform broke down. With assistance from IMF and World Bank the government formulated the Economic Recovery Programme (ERP), which was presented to donors at the 1986 consultative group meeting in Paris. A standby arrangement with the IMF was followed by a structural adjustment programme from the World Bank and many other donors started to increase their assistance to Tanzania substantially. The ERP was modified in 1989 to the Economic and Social Action Programme (ESAP) to include rehabilitation of physical infrastructure and measures to mitigate the social impacts of adjustment. In 1991 and 1994 the government entered into three-year Enhanced Structural Adjustment Facility (ESAF) arrangements with the IMF to support the second phase of the economic recovery programme.

The structural adjustment programmes which started in 1986 had deep impact on the economy and the life of every Tanzanian. Adjustment of the official exchange rate led to a strong devaluation of the Tanzanian shilling. Removal of price controls, import liberalization and reduction of import tariffs filled shops with a wide range of consumer goods. Free holding of foreign exchange enabled traders to open foreign exchange bureaus. Private banks started to operate after the liberalization of the banking system. More than 50,000 civil servants were retrenched. Producer prices for export crops were raised. The liberalization of the food market continued. Parastatals were privatized and cooperative unions restructured. According to World Bank figures agricultural GDP increased by 4.9 per cent annually between 1986 and 1991. In general economic growth was restored, fiscal deficits fell substantially and the rate of inflation was reduced somewhat (Mans, 1994).

The positive economic developments between 1986 and 1991 made Tanzania in the eyes of the World Bank one of the better performing countries with structural adjustment programmes in Africa (Cleaver, 1993). The national production of important food crops as maize and rice did, however, not grow further in the beginning of the 1990s and this started to worry observers with no connection to the World Bank. These observers (Bienefeld, 1995; Mbonile, 1995; Msambichaka and Naho, 1995; Putterman, 1995) stated that the structural adjustment programmes had no clear positive effects on agriculture in Tanzania. The disadvantage of the statements from the World Bank and their critics is that they are based on a limited number of years. The problem with data from few seasons is that short-term developments can disguise long-term trends. This paper presents agricultural data covering ten years of structural adjustment programmes in Tanzania and this is regarded as a better base for drawing conclusions. These data are then used to compare rural development during structural adjustment with rural development in Tanzania prior to World Bank/IMF backed reforms. The following gives first a short description of rural development policies during different periods in Tanzania's recent history and then a description of the agricultural performance during structural adjustment with a special emphasis on input distribution and consumption.

Rural development policies

Prior to socialism

The need for raw materials during World War II and the independence in 1947 of India, until then a major source of raw materials for Britain, forced the British government to take more interest in their protectorate Tanganyika. The colonial government became more involved in the production and marketing of several cash crops, and took a tolerant attitude towards the development of native cooperative movements. The period before independence in 1961 was characterized by a successful African commercial smallholder production of coffee and cotton and a successful formation of member-based marketing cooperatives for those two crops. The Kilimanjaro Native Coffee Growers Union (KNCU) and the Victoria Federation of Cooperative Unions (VFCU, dealing mainly with cotton) were effective in protecting the producers' profit margins. According to some people the VFCU was the largest cooperative organization in East Africa at the time. By 1964 it had built six cotton ginneries and acquired control over another four, had a monopoly on handling rice, sisal and maize, and operated two sisal factories, three oil mills and two rice mills (McLoughlin, 1967).

In 1961 the political party that led the country to independence, the Tanganyika African National Union (TANU), came into power. The cooperatives in turn began to have a major economic and socio-political impact and TANU leaders regarded them as a competitive political force although they had been closely associated with the cooperative movement during the independence struggle (Lele et al., 1989). From 1961 onwards the cooperative marketing system came increasingly under the political control of TANU. The 1961 drought and crop failure were used as an argument to institutionalize the cooperative system through the Agricultural Products Act of 1962. In 1963 the National Agricultural Products Board (NAPB) was given a monopoly on prices and marketing of all important agricultural products through cooperatives as agents. Growing complaints about inefficiency in management, cases of misuse of funds, and corrupt practices within the cooperatives were used as arguments for further government control (Geier, 1995). The agricultural development policy of the government was to push agricultural intensification. Just after independence (1962-65) several programmes were initiated to encourage the use of fertilizers and pesticides and to increase mechanization.[2] The use of more capital inputs in agriculture was expected to accelerate growth in agriculture and the economy in general. In the decade after independence grain exports exceeded imports and average annual growth rates by volume for coffee, cotton, cashew nuts, tobacco and tea varied between 7 and 18 per cent (Putterman, 1995). The rural development policy of the government appeared to be successful.

Under socialism

The Arusha Declaration in 1967 and the introduction of *ujamaa*, a socialist policy aiming at equal growth for all Tanzanians, changed the economy in many ways. The socialist policy led to the nationalization of banks, insurance companies, major industries, commercial farms and plantations, wholesale businesses and much of the retail trade. Agricultural production was expected to grow within the framework of *ujamaa* villages. Families from scattered holdings were moved to government planned new settlements for collective farming. Private plots of approximately one acre were allowed per family, next to the communal fields. The more concentrated settlement of people would enable the government to deliver services such as education, health and water in a more efficient way. When this so-called villagization campaign, launched in 1973, was completed in 1976, the vast majority of rural people had been resettled in new or already existing villages (Hyden, 1989).

The socialist strategy also meant further government control of marketing of agricultural products and of distribution of important agricultural inputs and consumer goods. In 1968 the National Milling Cooperation (NMC), a parastatal, became responsible for the processing of agricultural products. It was also granted a monopoly on imports of agricultural products. In 1973 the NAPB was split into parastatal crop authorities. These were given a wider mandate to include input distribution, credit, research and extension. In 1974 the parastatal crop authorities took over marketing functions from the cooperatives. In 1975 village multi-purpose cooperatives were installed and in 1976 the former member-based marketing cooperatives were officially dissolved. To facilitate the planning of farmers, crop prices were announced before the start of the season. The system of pan-territorial prices, that is the same prices in all villages, was introduced in 1974-75 (Geier, 1995). In 1975 the National Maize Programme was started in the ten most important maize-growing areas of the country.[3] It aimed at an increase in national maize production through government subsidized input packages of fertilizers, insecticides and hybrid seeds. A gradual removal of subsidies was planned. The consumer price of maize meal was heavily subsidized during the late 1970s. This was a concession to working-class demands based on the fact that minimum wages had been held constant for a number of years despite rapid inflation (Bryceson, 1987). The main objectives of the government were to provide sufficient food for the urban population at affordable prices, to stabilize farm incomes through price controls, to protect farmers from exploitation by private traders, to extract agricultural surplus for the development of the industrial and other sectors, to provide foreign exchange earnings for the government, and to reduce rural/urban and regional income inequalities. The system of pan-territorial producer and consumer food crop prices was installed to encourage production in potentially productive but remote areas and to guarantee a more equitable distribution of welfare (Amani et al., 1992).

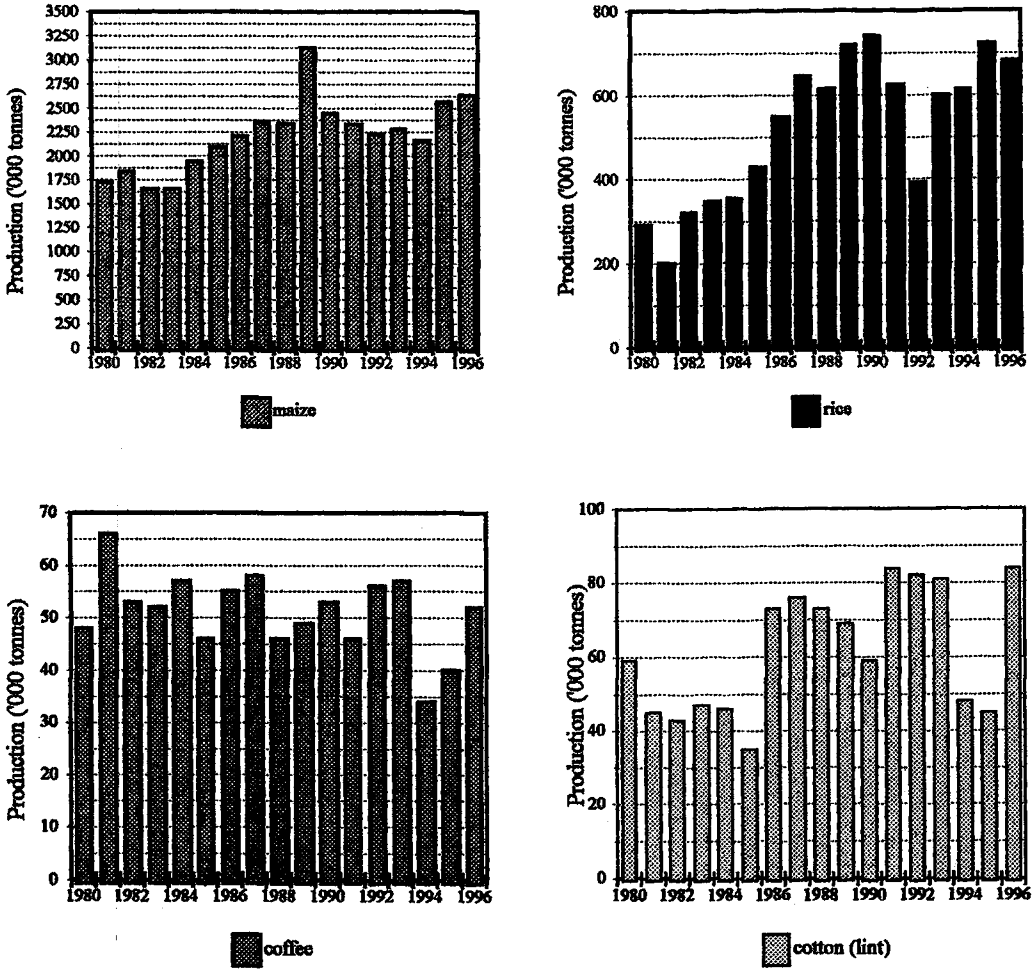
Data from FAO (1997)[4] show that the average annual growth rate by volume between 1967 and 1980 was 10.3 per cent for maize, 10.5 per cent for rice, 0.4 per cent for coffee and 2.0 per cent for cotton (lint) while the population was growing at an average annual rate of 3.0 per cent in that period. Between 1974 and 1980 the average annual growth rate for maize was even 17.7 per cent. The National Maize Programme had clearly succeeded in its aim to increase the national maize production. The pan-territorial pricing system for maize was, however, an indirect subsidization of production in such remote areas as Rukwa region, since transport costs were paid by the NMC or, in the end, the Tanzanian government (Geier, 1995). In the late 1970s and early 1980s the official producer price for maize was less than half of the free market ex-farm price in many parts of the country (Bryceson, 1987). This was the case for farmers near urban demand centers who were in fact taxed through pan-territorial pricing (Jayne and Jones, 1997). Confronted further with late payments and unreliable crop pick-ups farmers in these areas decided to stop or reduce their sales to the NMC and parallel, illegal trading in surpluses was widespread. The producer share of the world market price of the six leading export crops decreased steadily from 70.3 per cent in 1970 to 41.7 per cent in 1980, due to increasing overvaluation of the Tanzanian shilling and inefficiency in processing and marketing. In contrast to food crop producers, cash crop producers were often unable to find an alternative market.[5] Consequently farmers simply reduced their interest in these crops (Putterman, 1995). Instead they concentrated their efforts more on food crops and livestock. This process was most pronounced in the main cotton growing areas of Tanzania, that is Mwanza and Shinyanga regions, where farmers largely abandoned cotton cultivation and increased rice production (Meertens et al., 1995). This mainly explains the high average annual growth in rice production in the absence of a national rice programme during the 1967-80 period.

During structural adjustment

The failure of government controlled food production became obvious when Tanzania faced food shortages in 1980 and had to import 251 thousand tons of maize. These shortages were, however, mainly felt in the capital Dar es Salaam where an increasing number of urban consumers were primarily depending on food imports channelled through the NMC (Bryceson, 1987). The supplies of the NMC were insufficient to meet the demands because only farmers from the remote Southern Highlands were selling their surplus maize through the official channels. Here maize production was directly (inputs subsidies) and indirectly (transport costs) subsidized by the government. The subsidized consumer price for maize meal was further set with little regard for the NMC's actual marketing costs (Bryceson, 1987). By 1981 the cumulative debt of the NMC to the state-owned banks had reached 2.3 billion Tanzanian shillings (about 250 million dollars at that time) and the direct drain on the treasury[6] forced the government to reform the foodcrop sector (Putterman, 1995). One of the first steps was the reintroduction of a cooperative marketing and inputs distribution system in 1982. From 1984/85 season it was permitted to trade freely in food up to a maximum of 500 kilograms per individual per year. This quantative restriction was abolished in 1987. Subsidies on maize flour were abolished with the 1984/85 budget and first steps were taken to liberalize imports of (consumer) goods. In 1984/85 and 1985/86 the real producer prices of maize and other important food crops were raised sharply. The pan-territorial pricing system was replaced with a two-tier price regime which differentiated between premium (high potential for cereals) and non-premium areas (Geier, 1995).

One of the main objectives of the ERP (Economic Recovery Programme), as a part of structural adjustment, was to increase the output of food and export crops through better prices, improved product and input marketing, and an increased government budget for agriculture (Cromwell, 1996). A gradual shift from government control to privatization was seen as an important condition to reach this objective. The marketing and pricing of food and cash crops had to be liberalized completely, the monopoly export powers of crop marketing boards had to be removed, and several agricultural sector parastatals had to be restructured (World Bank, 1994a). The NMC was only allowed to manage the Strategic Grain Reserve and its usual easy access to commercial credit was simply terminated (Msambichaka and Naho, 1995). Under the Cooperative Act of 1991, only independent, voluntary, economically viable cooperative primary societies with democratically elected leadership could be registered. The supply and pricing of agricultural inputs had to be liberalized also. By 1988/89 mineral fertilizers had an implicit subsidy of up to 80 per cent. Due to increasing pressures on the budget the government decided to phase out the subsidy gradually from 70 per cent in 1990/91 to zero in 1994/95. During 1994 the subsidy on fertilizer imports, whose access was restricted to the parastatal TFC (Tanzania Fertilizer Company), was eliminated and pan-territorial pricing was discontinued (World Bank, 1994a).

Figure 2.1
Total production of maize, rice, coffee and cotton (lint) in Tanzania (1980-1996)



Source: FAO (1997)

Agricultural performance during structural adjustment

After five years of IMF/World Bank backed structural adjustment programmes, the World Bank concluded that the agricultural performance in Tanzania had improved substantially due to good weather and improved economic policies. Growth in the marketed output of food and export crops had been impressive and agricultural GDP increased according to the World Bank by 4.9 per cent annually between 1986 and 1991. The increased food availability eliminated the need for food imports by 1990. Export sales of traditional export crops increased by 68 per cent between 1985 and 1991 while nontraditional agricultural exports increased fivefold (Mans, 1994). Tanzania was seen by the World Bank as one of the better performing countries with structural adjustment programmes in Africa (Cleaver, 1993). This view was, however, not shared by others who had access to data stretching further than 1991. According to Msambichaka and Naho (1995) the economic liberalization had not boosted agricultural transformation but had rather contributed to demechanization of agricultural activities. Agricultural performance in Tanzania so far has not been impressive and incomes of rural households have been declining continuously while the real prices of consumer goods have been rising. Putterman (1995) stated that Tanzanian agriculture was witnessing modest growth at best. The rise in grain output proved not to be sustainable and the combined earnings from traditional export crops were down. Bienefeld (1995) concluded that Tanzanian farmers are facing a bleak future under the ERP. Producer price increases turned out to be small and short-lived and were mostly nullified by input price increases. Mbonile (1995) argued that the removal of subsidies on agricultural inputs had dealt a devastating blow to agriculture and rural development because it coincided with the time that farmers started to realise the importance of these inputs.

A look at the performance of the main food crops (maize and rice) and main cash crops (coffee and cotton) between 1980 and 1996 in Figure 2.1 will help to throw light on these contradicting views. Figure 2.1 shows that the production of maize and rice increased until 1989/90 and then did not grow further for the next six years. Food imports declined between 1986 and 1991 (Tanzania was even a net exporter for maize during 1987-91) but then started to increase again.[7] The production of coffee appears to have been declining continuously from 1980 onwards. Cotton production got a substantial booster in the first years of structural adjustment but that became much less after 1991. These trends are illustrated by five-year centered moving averages. The average total maize production was 1909 metric tons in 1982-86, 2520 metric tons in 1987-91 and 2374 metric tons in 1992-96. For total rice production these figures are respectively 400, 669 and 602 metric tons. Average coffee production declined from 53 to 50 to 48 metric tons. Cotton production increased first from 49 to 72 metric tons and then declined to 68 metric tons in those periods. This explains why evaluations of the structural adjustment programmes on agricultural development in Tanzania were positive for the period until 1991 and negative for periods stretching much further than 1991.

The World Bank (1994a) stated in its report on agriculture in Tanzania that their analysis had suffered from an inadequate or unreliable information base. It is indeed a fact that the available agricultural production figures in Tanzania, which are used by the World Bank and FAO, are not very accurate and have more an indicative value. There are estimations that more than 80 per cent of Tanzania's crop production is sold through markets beyond the reach of any form of statistical data gathering (Raikes and Gibbon, 1996). The food crop production figures used by FAO are, however, not based on marketed crop produce but on estimations of crop acreages and crop yield predictions according to water balance sheets for a particular season. The food crop production figures used by the World Bank (1994a) appear to originate from these FAO calculations.

It is, however, surprising that the World Bank used data from the 1971/72 Agriculture Census to give an indication of the average cultivated area of annuals per household for each region in Tanzania. For Mwanza region this is then supposed to be 0.73 hectares per household and for Shinyanga region 1.55 hectares per household. Agricultural surveys conducted in Mwanza and Shinyanga regions before 1971

(Rounce, 1949; Collinson, 1963 and 1964) got higher average cultivated areas per household than the ones from the 1971/72 Agriculture Census. More recent agricultural surveys conducted in these regions did also get higher figures. A rapid rural appraisal covering twelve villages in Mwanza region estimated that the average cultivated area per household was close to 2.4 hectares in the 1993/94 season (Meertens and Lupeja, 1996). A farming systems baseline survey conducted in Shinyanga region showed that the average cultivated area per household was close to 4.0 hectares in the 1991/92 season (Mashaka et al., 1992). This shows that the data from the 1971/72 Agriculture Census were not representative for these regions from the start. Higher figures for cultivated areas per household in combination with an increased total number of households give a higher total cultivated area in Tanzania than the 5.1 million hectares mentioned by the World Bank (1994a). During 1996 most newspapers mentioned that 6.3 million hectares, which is still a fraction of the total potential land for agriculture in Tanzania, were put under cultivation annually in Tanzania.[8] Due to changes in total number of households and total cultivated area, comparing agricultural production figures between years without modifications, the way we did in Figure 2.1, gives only part of the picture. To get a better idea of the productivity of the agricultural sector one has to compare the production per rural capita between different years. This is done in Table 2.1 for the production of maize, rice, coffee and cotton per rural capita in the form of five-year centered moving averages between 1967 and 1996.

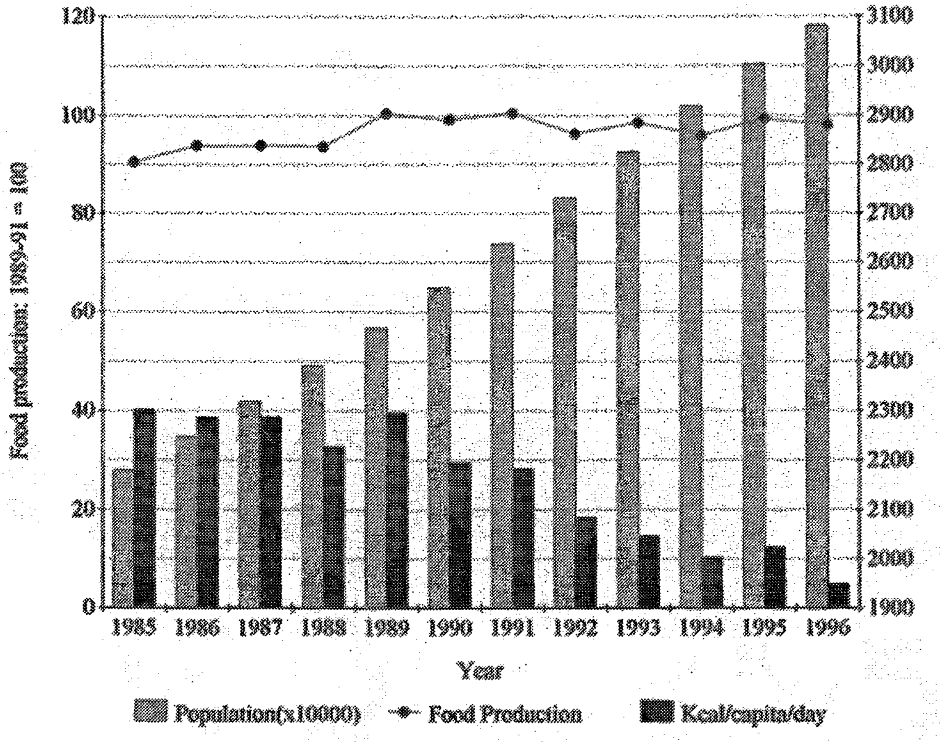
Table 2.1
Five-year centered moving average production of maize, rice, coffee and cotton per rural capita for Tanzania from 1967 to 1996

Period	Total rural population	Maize prod. (kg) per rural capita	Rice prod. (kg) per rural capita	Coffee prod. (kg) per rural capita	Cotton lint prod. (kg) per rural capita
1967-71	12,453,000	50.5	10.4	4.0	5.4
1972-76	13,999,000	72.6	18.9	3.9	4.6
1977-81	15,524,000	108.4	18.7	3.4	3.5
1982-86	17,512,000	109.0	22.8	3.0	2.8
1987-91	19,811,000	127.2	33.8	2.5	3.6
1992-96	22,232,000	106.8	27.1	2.2	3.1

Source: Based on data from FAO (1997)

Table 2.1 shows that the productivity per rural capita in the food crop sector improved during socialism (1967-81) and the first years of reform. This trend reversed after 1991. The productivity per rural capita in the cash crop sector declined steadily during socialism and structural adjustment was not able to alter this process for coffee. During the first years of reform the productivity in cotton improved but after 1991 it declined again. The productivity levels for cotton during IMF/World Bank backed reform (1986-96) were still far less than in the first years of socialism

Figure 2.2
Population, food and calories. Changes in Tanzania (1985-1996)



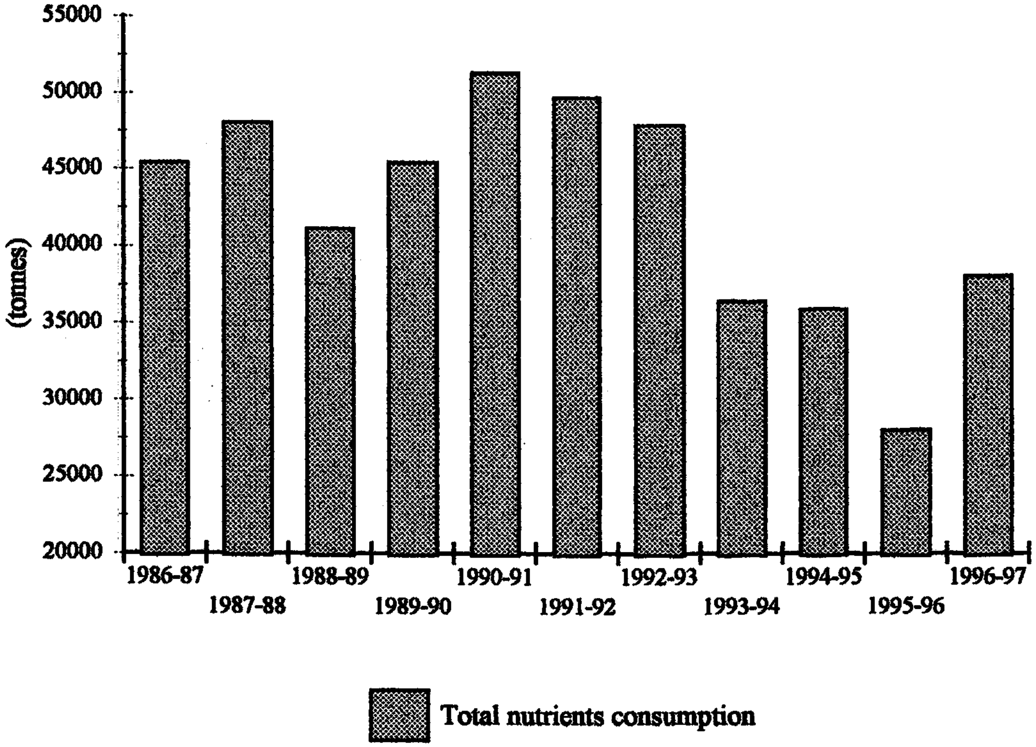
Source: FAO (1997)

(1967-76). The measures from IMF and World Bank were apparently not able to improve the agricultural sector in a sustainable way. Productivity levels per capita for all major food and cash crops during 1992-96 were all lower than in the 1987-91 period. Consequences of these lower productivity levels are lower incomes per household and lower intakes of calories per capita per day. The proportion of rural population to total population in Tanzania declined from 94 per cent in 1967 to 76 per cent in 1995 (FAO, 1997). So relatively fewer rural people have to produce more food and foreign exchange earning cash crops to feed and maintain services for relatively more urban people. Figure 2.2 shows that the amount of produced calories per day per capita in Tanzania from 1986 to 1996 declined more or less continuously and was never above the minimum acceptable level of 2,330 Kcal.[9] Higher productivity levels per rural capita in the food crop sector are needed to reverse this trend.

Liberalization and input supply

In its report on agriculture in Tanzania the World Bank (1994a) cited the conclusion from a survey of six farming systems across Tanzania[10] that "improving supplies of inputs to farmers in areas of high or moderate natural potential is the single most

Figure 2.3
Total fertilizer consumption (in tonnes of nutrients) in Tanzania (1986-1997)

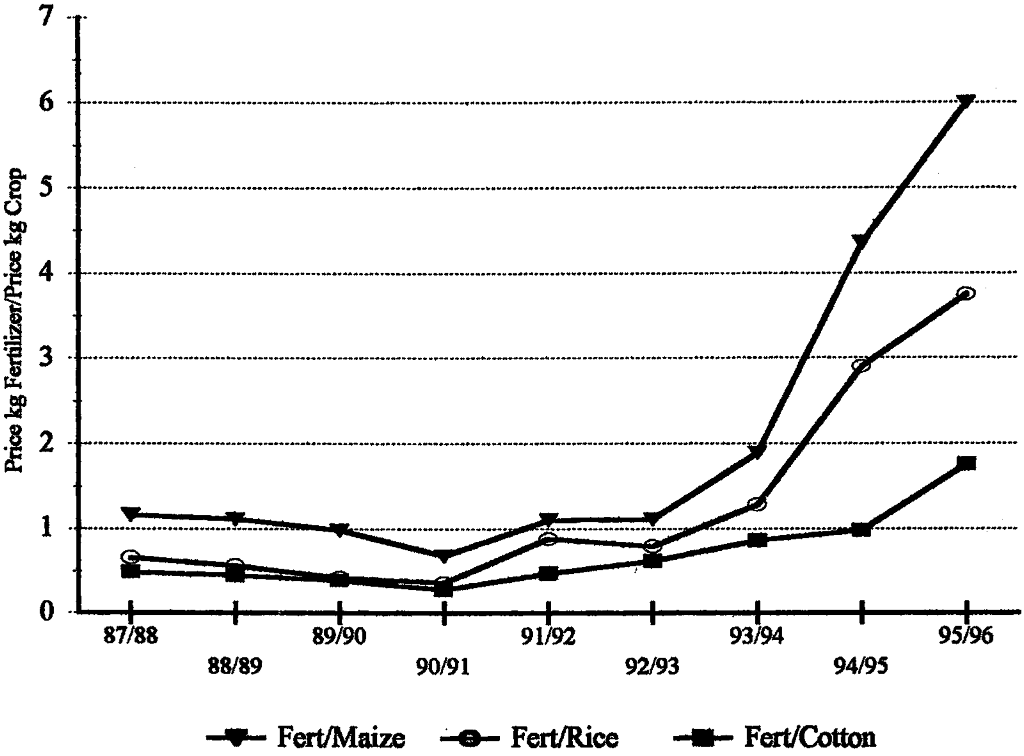


Sources: Kumar (1995) for 1986-87 till 1994-95 and FAO (1998) for 1995-96 and 1996-97

important measure that can be taken in the short term to stimulate agriculture in Tanzania". The World Bank report stated further that timely availability of the appropriate input is more important to the farmer than price. The fertilizer supply in 1992/93 was according to the World Bank well below the demand because government funds to cover the cost of the annual subsidy were limited. It was anticipated that due to the size of excess demand at current prices, the removal of the subsidy on fertilizer, and hence the removal of government intervention in the market, would improve supply and result in a net increase in fertilizer use. Another World Bank report (1994b) took this one step further by stating that "Tanzania is finding that removing large subsidies can ease supply constraints and result in greater fertilizer use, despite higher prices". Figure 2.3 shows, however, that the World Bank predictions on future fertilizer use in Tanzania were based on wrong assumptions.

As Figure 2.3 indicates, the consumption of fertilizers increased between 1986 and 1991 but then started to decrease to levels far lower than the consumption level of the 1986-87 season. Fertilizer prices increased slowly between 1986 and 1991 because the government did not allow TFC to raise these prices in accordance with the devaluation of the Tanzanian shilling. From 1991 onwards fertilizer prices increased sharply due to the gradual removal of the implicit subsidy which had amounted to 80

Figure 2.4
Ratios between fertilizer- and maize, rice, cotton farmgate prices in Mwanza region during 1987-1996



Source: Based on Meertens and Lupeja (1996) with additional data from the Kilimo/FAO Plant Nutrition Programme in Mwanza region, Tanzania

per cent in 1988/89. Increases in producer prices for maize, rice and cotton were higher than the fertilizer price increase during the 1986-91 period. This trend changed completely after 1991 when producer prices for crops increased far less than the fertilizer prices. Nominal increases in producer prices for crops failed to reflect the full extent of devaluation, although increases in input prices did so (Gibbon et al., 1993). Figure 2.4 shows how changes in farmgate prices for one kilogramme of fertilizer, maize, rice and cotton in Mwanza region affected the price ratio between fertilizer and these crops during IMF/World Bank backed reform (1986-96). Until the 1992/93 season these ratios were lower or close to 1.0 but after that they increased sharply. In 1995/96 the fertilizer/maize farmgate price ratio had reached 6.0, the fertilizer/rice ratio 3.75 and the fertilizer/cotton ratio 1.76. The profitability of using fertilizers declined correspondingly and many farmers reduced or stopped fertilizer consumption in 1993/94 and 1994/95 (Figure 2.3).

Data from Mwanza region serve as an example for processes which took place in each region of Tanzania. The consumption of fertilizers in Mwanza region is in fact low for Tanzanian standards. The greater part of fertilizers are consumed in the south of Tanzania where maize production was stimulated by the government in Iringa, Mbeya, Ruvuma and Rukwa regions.[11] The construction of a tarmac road from Dar es Salaam to these southern regions, the pan-territorial pricing of maize and fertilizers and the supply of fertilizers on credit by cooperatives led to high increases in fertilizer consumption and maize production. The removal of pan-territorial maize prices had initially no impact because the southern regions were regarded as premium areas. Marketing problems started for Rukwa farmers in 1988/89 when the NMC and the regional marketing cooperative were not able anymore to buy maize from farmers due to financial problems. This led to a serious decline in the producer price of maize because farmers were forced to sell their maize to private traders who paid far less than the official purchase price. At that time it was estimated that the average transport cost for maize from Rukwa to Dar es Salaam was 200 per cent of the producer price. The credit programme of the regional cooperative had to be abandoned at the same time due to poor repayment and the absence of refinancing options. It is not surprising that in the wet 1988/89 season only 50 per cent of the households in Rukwa region used fertilizers while this had been 70 per cent in 1987/88 (Geier, 1995). Reports in the national media showed that similar developments took place in Mbeya, Iringa and Ruvuma.[12] The decrease in demand for fertilizers was according to these reports mainly caused by the sharp increase in the price for fertilizers. The production of maize with or without the use of fertilizers was not profitable anymore on the infertile sandy soils in the south. Some maize farmers were already thinking about quitting agriculture while others shifted their attention to other crops. The collapse of maize production in the southern regions is reflected in the declining national maize production (Figure 2.1 and Table 2.1), the declining production of calories per capita per day (Figure 2.2) and the decline of fertilizer consumption (Figure 2.3). According to Raikes (1997) the World Bank and other donors had assisted in building up the maize production in the southern regions for 15 years and now left the farmers with no compensation for their errors in rural development policies.

The distribution of important, agricultural inputs had increasingly become a monopoly of government controlled parastatals and cooperatives during the socialist period. Agricultural development was pursued through agricultural intensification. The consumption of agricultural inputs in the main maize, cotton and coffee growing areas was stimulated through government subsidies on fertilizers, insecticides and hybrid seeds. Moreover these inputs were supplied on a credit basis. This strategy collapsed during structural adjustment when parastatals and cooperatives, who had built up huge debts to the state-owned banks, were denied further access to commercial credit. The supply of agricultural inputs had to be liberalized and this involved the elimination of government intervention. The gap had to be filled by private traders. This worked quite well in the areas with high demand for inputs and favourable road networks like Iringa, Mbeya and Ruvuma regions. By 1991/92 over 95 per cent of the fertilizer in Iringa was sold through some ninety private retailers (World Bank, 1994a). In areas with poor road networks (Rukwa region) and/or low demand for inputs (Arusha and Mwanza regions), private traders were not able to replace the government and availability of agricultural inputs declined. Private traders in Arusha region could not profitably supply inputs to more remote villages due to high transport costs and low demands. In general they were not supplying fertilizer on credit (Putterman, 1995). The distribution of most inputs in Mwanza region after 1992 had to be done by a few private traders without transport facilities and limited capital. No wonder that most agricultural inputs were not available in many villages during the 1993/94 season (Meertens and Lupeja, 1996). The government tried to compensate these adverse effects of liberalization on the supply of agricultural inputs in certain regions through the Agricultural Inputs Trust Fund. This fund started in 1995/96 and provided loans with fairer interest rates than commercial banks to private traders for the importation and distribution of agricultural inputs. The capacity of this fund was, however, only enough to assist a few private traders. The size of the loans was further often insufficient for the distribution to farmers of expensive inputs such as cotton insecticides.[13] In many parts of Tanzania private traders established monopolies for the supply of agricultural inputs and were able to set prices at unnecessary high levels due to lack of competition. During liberalization most private traders found it more profitable to deal with other items than agricultural inputs. Traders are for example interested in buying cotton and rice from farmers but not in supplying these farmers with agricultural inputs. Recent World Bank reports admit that greater attention should have been given earlier to strengthening the local private sector through better access to credit, lowering real interest rates and inflation, higher transparancy of tax assessments and collections, and streamlining of the investment approval process (Mans, 1994). Others doubt if the small quantity of fertilizers consumed in Tanzania (100,000-150,000 tons per year) can support the introduction of many private traders in the supply of fertilizers (Kumar, 1995).

Conclusions

Structural adjustment was meant to lead to an increased output of food and export crops through better producer prices, improved product and input marketing and an increased government budget for agriculture. Ten years have passed since the start of IMF/World Bank backed structural adjustment in Tanzania and there are no signs that the objectives in the agricultural sector will be reached. In fact matters have became even worse. Productivity levels per rural capita for important food crops (maize and rice) and important cash crops (coffee and cotton) are presently going down while the population keeps growing at a rate of 2.9 per cent anually.[14] The consequences are a declining production of calories per capita and a decreasing amount of foreign exchange from cash crops per capita.

Although the producer share of the world market price of export crops generally increased, there was no real price increase for export crops due to devaluation of the shilling and depressed world market prices. According to Barratt Brown (1995), the cause of this in effect downward trend in prices for export crops was in part the World Bank's encouragement of all primary commodity producers to pay off their debts by increasing their exports. The increase in producer prices of food crops could not keep up with the sharp increase in prices for consumer goods due to the devaluation of the shilling. The liberalization of the food crop sector lowered prices even further in the more remote parts of the country. Due to the very bad condition of most rural feeder roads only few private traders were able to buy food crops in remote villages. Most farmers in these villages had no alternative than to accept the very low prices offered by these traders. Tanzania's ERP assumption that market forces would raise rural producer prices rested on the belief that administered prices contained a large element of rent extracted from agriculture by an urban elite. A redirection of this rent would increase real producer prices. This assumption was inappropriate for all those households not living close to urban demand centers who were growing maize as a cash crop. Their rural incomes were in fact better protected than urban incomes in the fifteen years prior to the start of ERP in 1986 (Bienefeld, 1995). Within agriculture, priority was given to food crops and the National Maize Programme was a clear example of the government efforts to increase food production. The investments from the government in input supply, credit disbursements and storage/transport facilities were a stimulus for food production instead of a taxation (Jayne and Jones, 1997). Bevan et al. (1993) found that the effect of macroeconomic policies on agricultural output via their effect on producer prices is weak. Microeconomic policies (markets, infrastructure and agricultural services) are more important. Even within the World Bank people start to admit that Tanzania's experience shows the limits of macroeconomic policy reforms if the necessary microeconomic foundations are not in place (Mans, 1994).

Liberalization of agricultural export marketing was seriously delayed since IMF/World Bank backed reform started in 1986. Only during 1994/95 was the private sector allowed to enter the marketing of export crops. This delay was caused by the influence of political groups who were still sticking to the socialist strategy of the 1970s. The entrance of the private sector was further far from smooth because parastatals and cooperatives still had many competitive advantages due to slow reforms. Liberalization of the supply of inputs caused a decrease in the availability of agricultural inputs in many more remote parts of the country. Too few traders were attracted by this type of business after the sudden switch from government control to private enterprise. The local private sector had been discouraged since the late 1960s and was slow to react to the new opportunities offered by the reforms. The elimination of subsidies on agricultural inputs and the abolishment of credit facilities by cooperatives caused a decrease in the demand and consumption of these items by the farmers. The combination of low maize producer prices and high input prices increased the price ratio between inputs and maize in a serious way. In the main maize producing areas this led to a decrease in maize production which was reflected in the decreasing national maize production and, due to the importance of maize for the national food production, in the lower intake of calories per capita per day. Similar developments in price ratios between inputs and crops caused less spraying of cotton with insecticides and in general no sign of intensification in the production of rice or any other crop in Mwanza region (Meertens and Lupeja, 1996).

The agricultural sector is very important for the Tanzanian government because it generates a large part of the foreign exchange for the country. It is therefore surprising that the government did not stimulate the cash crop sector like it did for the food crop sector during the socialist years. The strategy during that period was to obtain more foreign exchange from industrial development than from cash crops. According to the World Bank, government funds for agricultural research and extension have been insufficient for a long time and have to be raised to more appropriate levels (World Bank, 1994a). Recent budgets show, however, no sign of increased allocations to agricultural services. Central government budgets are constrained due to the large size of the civil service and the continuously increasing debt servicing obligations and social sector (education, health) demands. During

1996/97 more than 30 per cent of the recurrent revenue was allocated to debt servicing while about 40 per cent was needed for wages of civil servants.[15]

Structural adjustment programmes have without doubt had positive effects on the macroeconomy of Tanzania. However, this paper shows clearly that the results in the agricultural sector are disappointing. Liberalization of this sector did not increase the production of food crops in a sustainable manner and did not increase the production of export crops in a convincing way. According to the World Bank these problems were caused by a slow pace of reform. Faster liberalization of agricultural export marketing and greater attention to strengthening the private sector would be the keys to boost growth (Mans, 1994). Others find that modifications are required in the structural adjustment policies for the agricultural sector. According to Msambichaka and Naho (1995), the issue of subsidies to agriculture should not only be subjected to the dictates and doctrines of a free market economy. Putterman (1995) adds that government participation in the form of subsidies or any other approach may be desirable concerning the supply of inputs or the provision of small farmer credit. This view also gets support from the side of environmentalists. Their argument goes that the increase in fertilizer prices and the reduction in credit availability has forced small farmers to increase cultivation of marginal areas, which generates more deforestation and erosion problems. Retaining subsidies on farm inputs and providing credit for private traders and small farmers to buy fertilizer gives benefits through intensification of production which will outweigh the budgetary costs (Cromwell et al., 1996). However, external pressures from some donors blocked any possibility of subsidizing prices of fertilizers for the 1997/98 budget.[16]

The agricultural development in Tanzania during IMF/World Bank backed structural adjustment programmes is not unique for Africa. Barratt Brown (1995) described how Ghana during structural adjustment programmes first enjoyed five years of recovery in national income and food production per head which were then followed by years with declining productions of food crops and the main cash crop, cocoa. The absence of support for non-cocoa food production and the reduction of farm input subsidies created disincentives to grow food. The collapse of the world market price of cocoa in the early 1990s led to a decline in cocoa production. Reardon et al. (1997) showed that the availability of inputs deteriorated, the price ratios between inputs and crops worsened and thus the consumption of inputs stagnated or declined during structural adjustment in Burkina Faso, Mali, Niger and Senegal. Koning et al. (1997) indicate that in several West African countries food production can not keep up with population growth and that it is questionable if structural adjustment had positive effects on agricultural development and food security in West Africa. Jayne and Jones (1997) showed that structural adjustment led to declining per capita productions of cereals in Zimbabwe, Zambia, Malawi, Kenya, South Africa and Tanzania. According to them Tanzania has probably been the most positive record for grain production. This paper has shown, however, that the record for grain production was far from positive in Tanzania during structural adjustment.

White (1996) stated that adjustment policies which go too far in reducing the role of the state may end up stunting development rather than promoting it. Rectifying these shortcomings of structural adjustment programmes will require higher inputs of public resources in the agricultural sector and may call for a greater role for the state rather than a reduced one (White, 1996). Also for Tanzania it has become clear that there are signs of negative developments from disappearing government involvements. A good example is the supply of agricultural inputs. Contrary to World Bank predictions the consumption of mineral fertilizers declined due to unfavourable crop-fertilizer price ratios. The current farmgate prices for crops and inputs prevent the profitable use of agricultural inputs by allmost all types of farming households. Private traders failed to improve the supply of these inputs and were not attracted to this type of business due to dwindling demands from the farmers. Any strategy aiming at a higher consumption of agricultural inputs in Tanzania will be tempted to reconsider interventions in the pricing of crops and/or inputs from the side of the government. The costs involved might be lower than the expenses for importing food. Further government involvements are needed to guarantee the quality of cash crop products (cotton lint, coffee berries) for sale at the world market and to control the quality of agricultural inputs (seeds, mineral fertilizers, biocides) supplied by private traders.

Notes

1. The informal market premium for US dollars was 800 per cent in 1985 (Mans, 1994)
2. In the cotton growing areas near Lake Victoria the government launched a programme in 1964/65 to expand the use of mineral fertilizers in cotton rapidly. With technical assistance from the Israeli government the so called Agridev pilot schemes were initiated between 1962 and 1964 near Lake Victoria. The general objective was to introduce a modern system of agriculture relying heavily on mechanization, fertilizers, insecticides and where possible irrigation. In 1964/65 the government also launched a large-scale programme to mechanize and intensify the production of cotton through group mechanization schemes resembling the Agridev schemes. Spraying of cotton had to be done by tractor-drawn sprayers and, increasingly, by aircraft (McLoughlin, 1967).
3. Arusha, Dodoma, Kilimanjaro, Mbeya, Morogoro, Rukwa, Ruvuma, Tabora, Iringa and Tanga (Bryceson, 1987).
4. The FAO document *The State of Food and Agriculture 1997* included a computer diskette with time series data for about 150 countries.
5. There were some exceptions in areas close to national borders. For example a substantial amount of coffee production from Kilimanjaro region was smuggled into Kenya (Putterman, 1995) and from Kagera region into Uganda.
6. By the early 1980s the costs of food and input subsidies had become unbearable: losses made by official marketing agents had reached an equivalent of 15 per cent of GDP (Amani et al., 1992).
7. Import and export data obtained from *FAO Trade Yearbook* Vol. 42 (1988), Vol. 45 (1991), Vol. 48 (1994) and *FAO Statistics Series* No. 91 (1989), No. 109 (1992), No. 127 (1995).
8. This figure was for example mentioned in "Looking ahead in agriculture" in the *Business Times* of 1-11-1996 and seemed to be the current official figure from the Ministry of Agriculture.
9. This level of minimum acceptable calories per capita per day was mentioned in a World Bank report (Cleaver, 1993).
10. The quoted conclusion was taken from the final report (1992) of the "Agricultural Diversification and Intensification Study" by the Oxford University Food Studies Group in collaboration with the Sokoine Agricultural University of Tanzania.
11. From 1989 to 1991 the southern regions (Iringa, Mbeya, Ruvuma and Rukwa) consumed 68 per cent of all fertilizers in Tanzania while the regions around Lake Victoria (Mwanza, Shinyanga, Mara and Kagera) consumed only 3 per cent (World Bank, 1994a).
12. Examples are "Fertilizer use decreases" in the *Daily News* of 20 October 1995 and "Agricultural sector needs revamping" in *The Guardian* of 8 March 1996.

13. Personal communication with J.J. Makoye, Shinyanga regional cash crops subject matter specialist.
14. Population growth based on population data from FAO (1997).
15. These percentages were stated in "1997/8 budget: social services and marginalised groups" in the *Financial Times* of 23/29 July 1997.
16. From a review of the 1997/8 budget in "1997/8 budget: social services and marginalised groups" in the *Financial Times* of 23/29 July 1997.

Acknowledgements

Thanks to the assistance of Yves Gillet, the former Chief Technical Adviser of the Kilimo/FAO Plant Nutrition Programme, I was able to use some recent publications. Thanks go further to Dr Niek Koning, Dr Joost Brouwer and Dr Niels Röling from Wageningen Agricultural University for their comments on earlier drafts.

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*H.C.C. Meertens[1], L.O. Fresco[2] and W.A. Stoop[3]**

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

Abstract: The changes in agricultural production systems over the period 1875 till 1990 have been analysed for three districts belonging to Sukumaland, Tanzania. The analysis is based on historic information for the early period, on data from agricultural studies conducted in 1945 and 1961, and on recent field studies in 1990-92.

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

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

Keywords: Farming systems; Sustainability; Tanzania; Rural development

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** Published in *Agriculture, Ecosystems & Environment 56 (1996) 203-215*
Accepted 18 August 1995

Introduction

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

In contrast, to the above 'Malthusian' thoughts, Boserup (1965) argued that population growth is a pre-condition for development since it eventually forces the population to intensify land use. As a result, the growth rate of food production will also accelerate (Boserup, 1981). This view is supported by a recent field study in the Machakos District of Kenya by Tiffen and Mortimore (1992). In this area population density had reached 135 inhabitants per km^2 in 1990; yet the value of output per caput and per hectare increased by factors of approximately three and ten respectively over the period 1930-1990, whereas erosion decreased considerably. It is unclear, however, to what extent these favourable developments are a function of the prevailing agro-ecological conditions which elsewhere in Africa are often more marginal. Furthermore, the relationship between population growth and agricultural expansion is unlikely to be a linear one. It is still poorly understood to what extent phases of land use intensification are followed by extensification and vice versa.

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

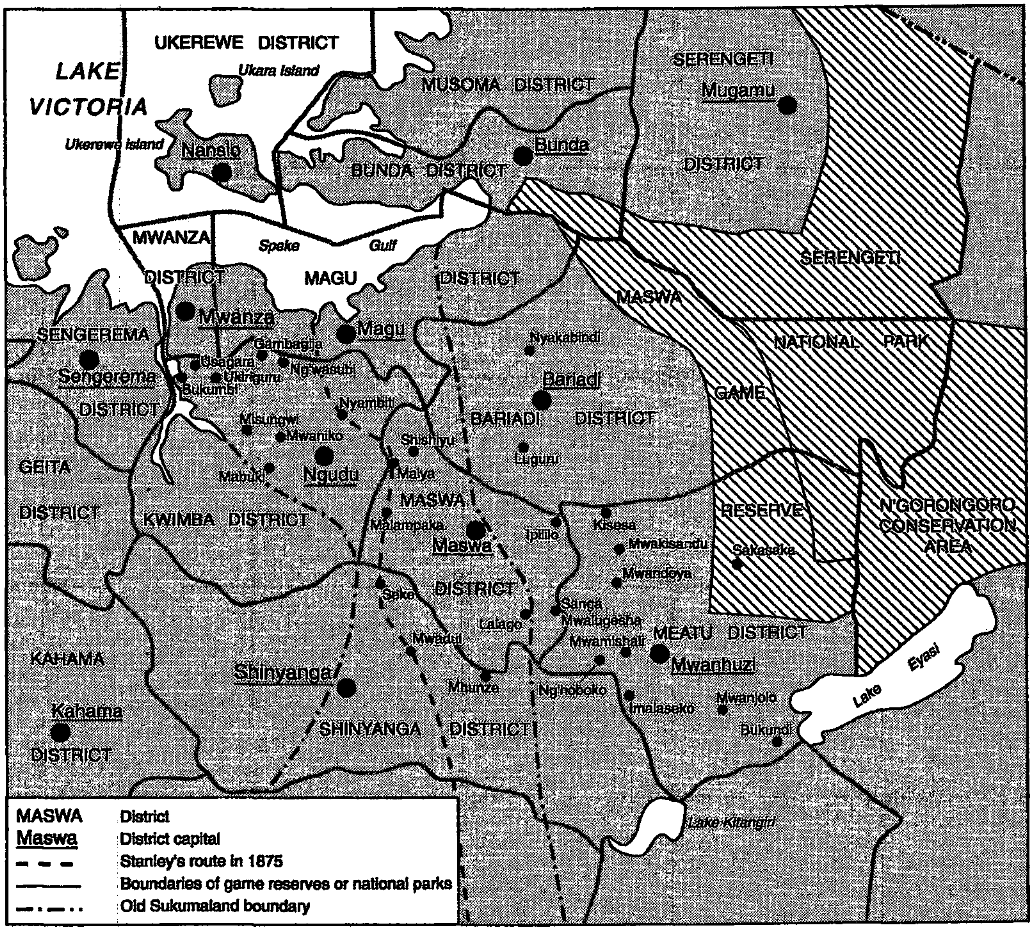
Sukumaland offered an excellent opportunity for this type of comparison. Detailed data are available from earlier studies in 1945 and 1962 and can be compared with data from 1990-1992. The area is characterized by considerable variations in agro-ecological potentials: the climate is semi-arid with unpredictable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

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

Materials and methods

Sukumaland mainly covers the area between the Speke Gulf of Lake Victoria and Lake Eyasi. It consists of ten districts: Ukerewe, Mwanza, Magu, Sengerema, Geita, Kwimba, Bariadi, Maswa, Meatu and Shinyanga (Fig. 3.1). The Sukumaland study by

Fig. 3.1
Map of Sukumaland



Source: Meertens et al., 1995

Meertens et al. (1995) is based on results obtained from agricultural surveys (ICRA, 1990; Bantje, 1991; Meertens and Ndege, 1993) conducted around 1990. Subsequently these results are compared with similar data from 1945 and 1962, as reported in the literature (Rounce, 1949; Collinson, 1963; Collinson, 1964; Collinson 1972); in addition, historical reports (Stanley, 1899) about the area are reviewed. The data sets for 1945, 1962 and 1990 are interpreted against the agro-ecological conditions of Sukumaland in terms of its climate, soil catena and predominant vegetation, wildlife/livestock and pests. The major political events and the associated changes in agricultural policies that have occurred from 1875 to 1992 were also taken into account.

The setting

History

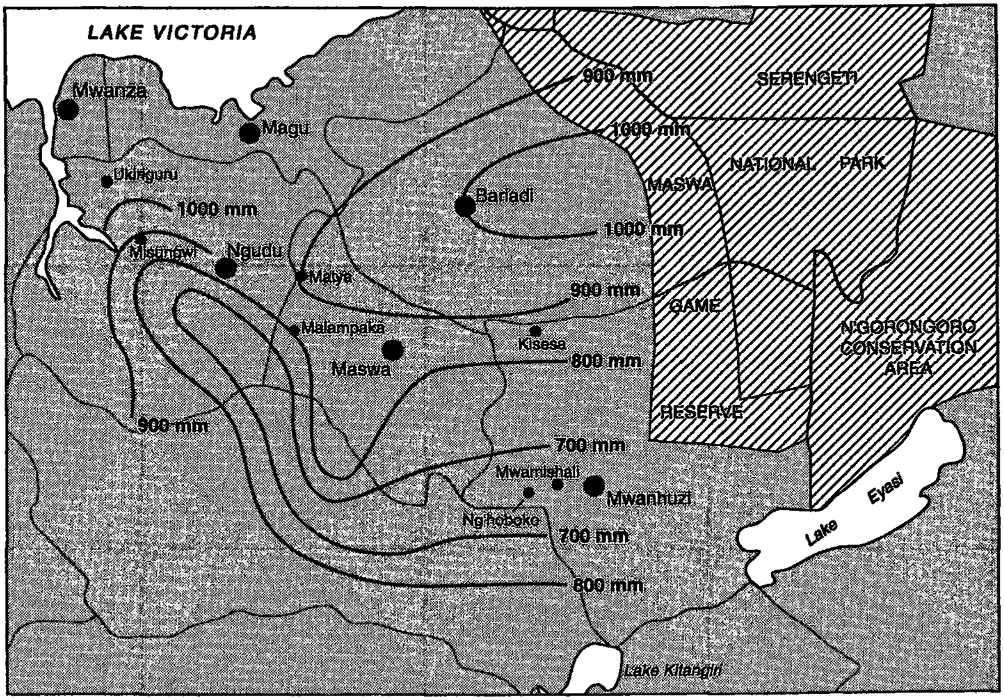
The major historic events that most profoundly affected the Sukumaland agriculture have been summarized in Table 3.1. People started to settle in Sukumaland in the 16th century. In 1875 Henry Morton Stanley travelled through Sukumaland and described it as a land of plenty (Stanley, 1899). At that time Sukumaland was composed of several chiefdoms with frequent wars among them. Most probably these wars were sparked by the profitable trade of war prisoners as slaves. In 1890 Tanganyika became a German colony and the imposed military rule practically ended the warfare among the chiefdoms. Tanganyika became a British protectorate after the First World War. It was only after the Second World War, with the increased demands for raw materials from Europe, that an ambitious agricultural development scheme was started for Sukumaland (1947-1956).

After independence (1961), the Arusha Declaration of 1967 set in motion a socialist strategy aimed at nationalization and the creation of Ujamaa villages. By 1985 the Tanzanian government made an agreement with the IMF to liberalize the economy, which also led to abandoning gradually the Ujamaa philosophy.

Table 3.1
Main events in Sukuma agricultural history

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

Fig. 3.2
Rainfall in Sukumaland



Source: Meertens et al., 1995

Agro-ecology of Sukumaland

The area has a moderately warm climate with daily temperatures varying between 15° and 30°C throughout the year and a mean annual daily temperature of about 23°C. Average annual rainfall ranges between 700 mm and 900 mm with higher rates (1000-1100 mm) near Lake Victoria and lower ones (400-500 mm) near Lake Eyasi. Fig. 3.2 shows that the rainfall decreases gradually from Lake Victoria to Lake Eyasi and from Serengeti National Park to Maswa District.

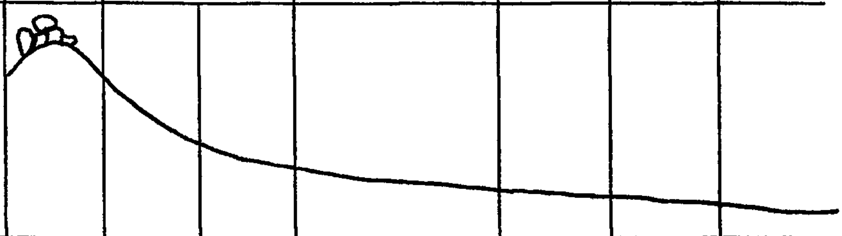
Generally, the rains start by mid-October and end by mid-May. The pattern is bimodal with peaks in November-December and March-April; prolonged dry spells are common in January and February. The dry season is from June-October. Apart from this general pattern the rainshowers are very localized and unpredictable.

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

Typical soil catenas, first described by Milne (1947), have developed in the granite parent material (Fig. 3.3). The local Wasukuma population has a thorough knowledge of the catenas and recognizes the predominant soil types by specific names. Moreover, the different cropping systems and local production technologies are

Fig. 3.3
Soil catena of Ukiriguru

landscape feature	granite hill with tors	upper footslope		lower footslope	valley margin	valley floor	seasonal swamp



type of soil and characteristics	dark grey loam, skeletal	brownish red loam direct on granite	brownish red loam murram in sub-soil	grey sand, irregular murram in subsoil	hard-pan soil, not calcareous	black sandy clay, calcareous	heavy black clay
local name	*luguru*	*ikurusi*	*isanga*	*luseni*	*ibambasi*	*itogolo*	*mbuga*

Source: based on Milne (1947)

closely adapted to soil characteristics as discussed in a recent paper by Ngailo et al. (1993). The distribution and relative importance of the different soil types along the catena are greatly influenced by the steepness and length of the slope. For the area around Ukiriguru (Fig. 3.1) the dominant soil type in the catena is Luseni, which is an acid, bleached sandy soil with poor structure and very low natural fertility. Closer to Mwanza the hills are much steeper; here the dominant soil type is Isanga, which is a coarse, sandy to gravelly sandy loam. Clayey soils are almost absent in this catena.

Elsewhere in Sukumaland (Kwimba, Bariadi and Maswa Districts) most valleys are broad and gently undulating to almost flat so that the catenas are longer than the one in Fig. 3.3. The dominant soil types are then Ibambasi and Itogolo which are alkaline sandy clay hardpan soils.

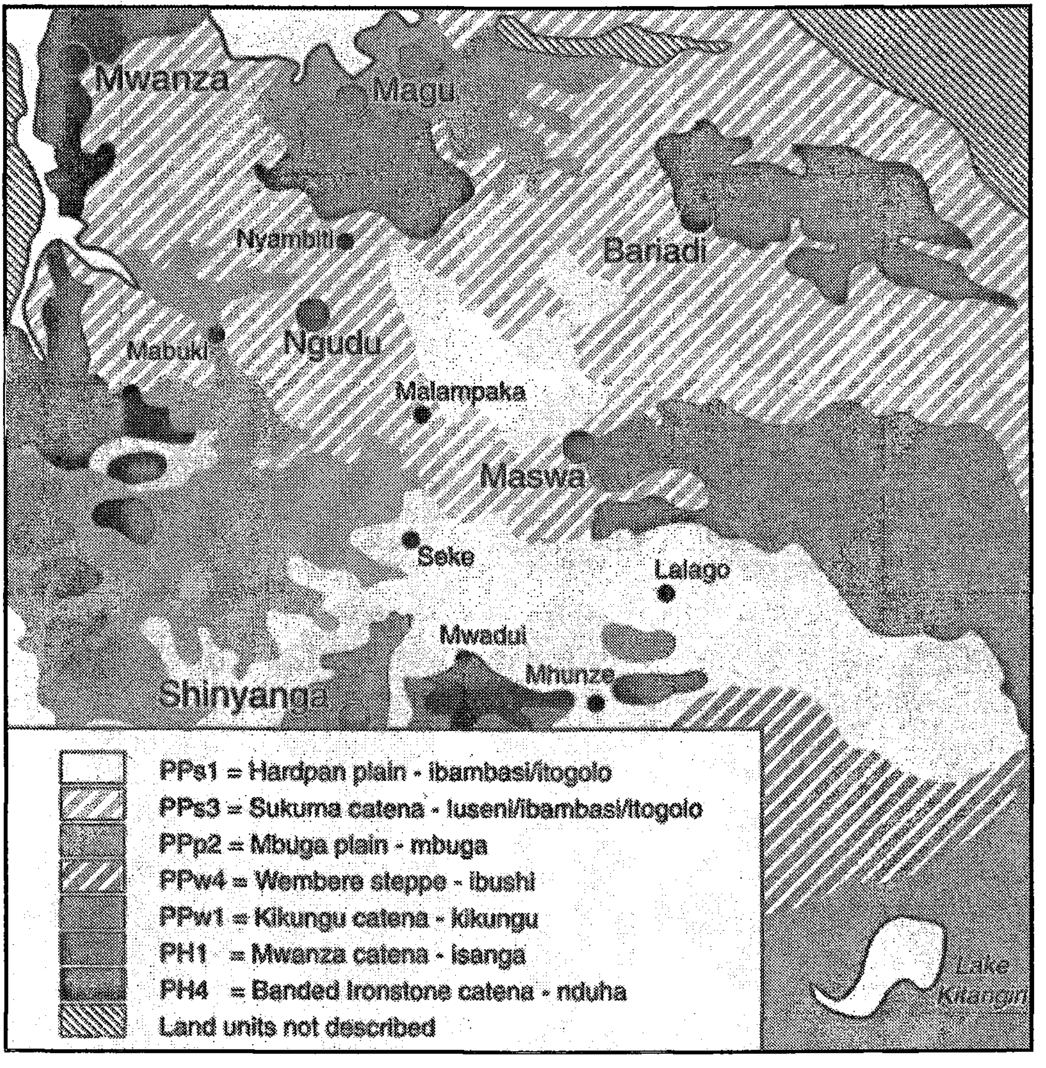
Besides the catenas there are vast, almost flat, plains which developed on old alluvium. These plains are common in Maswa, Meatu and Shinyanga Districts; the dominant soil types are Ibambasi and Itogolo or Mbuga, a dark cracking clay, or Ibushi, a calcareous friable, clay loam. The respective locations of the catenas and valleys in Sukumaland are indicated in Fig. 3.4.

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

Changes in Sukumaland agriculture

Throughout history there have been frequent changes in farming practices and consequently in the intensity of farming. For European agriculture these changes

Fig. 3.4
Physiography and soils in Sukumaland



Source: Meertens et al., 1995

have been described in detail by Slicher van Bath (1977) for the period 500-1850. Such studies serve to identify the crucial factors that have triggered agricultural developments, as well as their impact on agricultural production and its sustainability for specific regions. Although the historic data base for African agriculture is much less detailed than for Europe, there are remarkable similarities in the types of developments and their causes.

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

Obviously, a most important factor in agricultural developments in Sukumaland during this last century has been the large population growth. Differences in population density are associated with a differential land use intensification pattern, as shown by the farm management data from 1945, 1962 and 1990 for three subregions, within the boundaries of Old Mwanza, Old Kwimba and Old Maswa Districts. The prefix 'old' is used because administrative boundaries have changed over the years. In 1945 and 1957 Mwanza District included Usagara Division and parts of Magu and Geita Districts; Maswa District included the areas that are nowadays Bariadi and Meatu Districts (Fig. 3.1).

Population density

Population density has always been higher in the Mwanza and Kwimba Districts than in the Eastern Districts of Maswa and Meatu (see Fig. 3.1 and Table 3.2). After the Sukumaland Development Scheme (1947-1956) an overall increase in population and livestock density took place in almost every part of Sukumaland because the nearby possibilities for migration were limited to the Maswa Game Reserve only.

Table 3.2 presents the changes in population density for various parts of Sukumaland since 1945. The population in Usagara Division has increased to 114 persons per km^2 in 1988 so that all land is currently occupied and almost no fallow exists anymore. The average cultivated area per household decreased to 1.77 ha and the per capita availability of arable land to 0.27 ha in 1990 (Table 3.3). Households therefore had to obtain their food and cash from smaller and fewer fields; the resulting agricultural intensification led to a land-use intensity factor (*R*)[1] between 80 and 100.

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

Table 3.2
Population density changes in different parts of Sukumaland since 1945

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

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

Table 3.3
Changes in average household size, arable land per capita and total cropped area per household over the period 1945 to 1991 for three regions in Sukumaland

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

Land use patterns

The initial settlers may have moved to Sukumaland several centuries ago because of the abundant game living in the grass plains. These grasslands were located on hardpan soils where consequently very few trees could grow. Moreover, because of the limited shade the tsetse flies also were absent. The grasslands were bordered by tsetse-infested thorn bushlands. Thus, as arable farming gradually replaced hunting, the first settlements were concentrated in Kwimba and parts of Bariadi, Maswa and Shinyanga Districts (Fig. 3.1 and Fig. 3.4) and comprised a mixed livestock-arable farming. The cropping component of the system occupied the sandy soils on the upper slopes near the rock outcrops which are easy to cultivate with handtools.

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

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

A next phase in the agricultural extensification process started with the introduction of ox cultivation in 1934. Only after 1945, with the start of the Sukumaland Development Scheme (1947-1956) and the expansion of cotton production (Fuggles-Couchman, 1964), did the ox ploughing lead to large increases in farm sizes (from an average of 2.5 ha to 4.0 and even 5.0 ha in Meatu). Under this Scheme 30000 people moved in 5 years to the Geita District. Moreover, the clearing of tsetse-infested bush in Meatu District provided additional areas for cattle grazing (Fuggles-Couchman, 1964).

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

Cropping patterns

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

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

Throughout Sukumaland the main cash crop around 1945 was cotton. Its production was further enhanced by the extension of the railway line from Tabora to Mwanza in 1928. This drought-tolerant crop was most important near the Lake and during 1935-44 one half of the total Sukumaland cotton production came from Old Mwanza.

Table 3.3 shows that by 1990 the cropped area per household and arable land per capita had declined substantially in Old Mwanza and Old Kwimba due to the increased population density. For Old Maswa where the overall population density is lower these trends are opposite. During the same period also the relative importance of different crops has drastically changed from the 1945 situation (Fig. 3.5). Most remarkable is the decline in dryland cereals (in particular bulrush millet and sorghum) and the increased importance of rice in all three of the districts. Moreover, the expansion in cotton production during the 1960s has been followed by a steep decline in the 1970s and 1980s. Bulrush millet, important in 1945, is hardly cultivated in 1990; sorghum became one of the many crops intercropped with maize, which became the predominant dryland cereal crop. Thus by 1990 maize and rice had become the two major cereal crops.

Apart from these overall trends there have also been important, local changes (see

Table 3.3 and Fig. 3.5). In Usagara Division (Old Mwanza) a considerable decrease in available land per household and per capita has resulted in intensification of crop production. Intensification leading to an increased production per unit area has resulted mostly from higher labour inputs (weeding, preparing and applying manure) and to a much lesser extent from capital inputs such as mineral fertilizers. In this process sorghum was replaced by selected maize and rice varieties, since the latter crops are more responsive to intensive cultivation. Maize yields increased in Usagara from 800 kg ha^{-1} around 1945 to 1500 kg ha^{-1} in 1990, while rice yields increased from 1700 kg ha^{-1} to 3375 kg ha^{-1} over the same period (see Table 3.4). Likewise cassava has completely replaced bulrush millet on the exhausted Luseni soils because of its higher yield potential under these conditions. Moreover, by 1990 intensive cultivation of horticultural crops, in particular tomatoes, for the nearby Mwanza market had replaced cotton as a cash crop; simultaneously the significance of off-farm employment increased as well.

Table 3.4
Changes in maize and rice yields

	Usagara Division		Sukumaland	
	maize (kg ha^{-1})	rice (kg ha^{-1})	maize (kg ha^{-1})	rice (kg ha^{-1})
1945[a]	800	1700	800	1700
1990[b]	1500	3375	785	1660

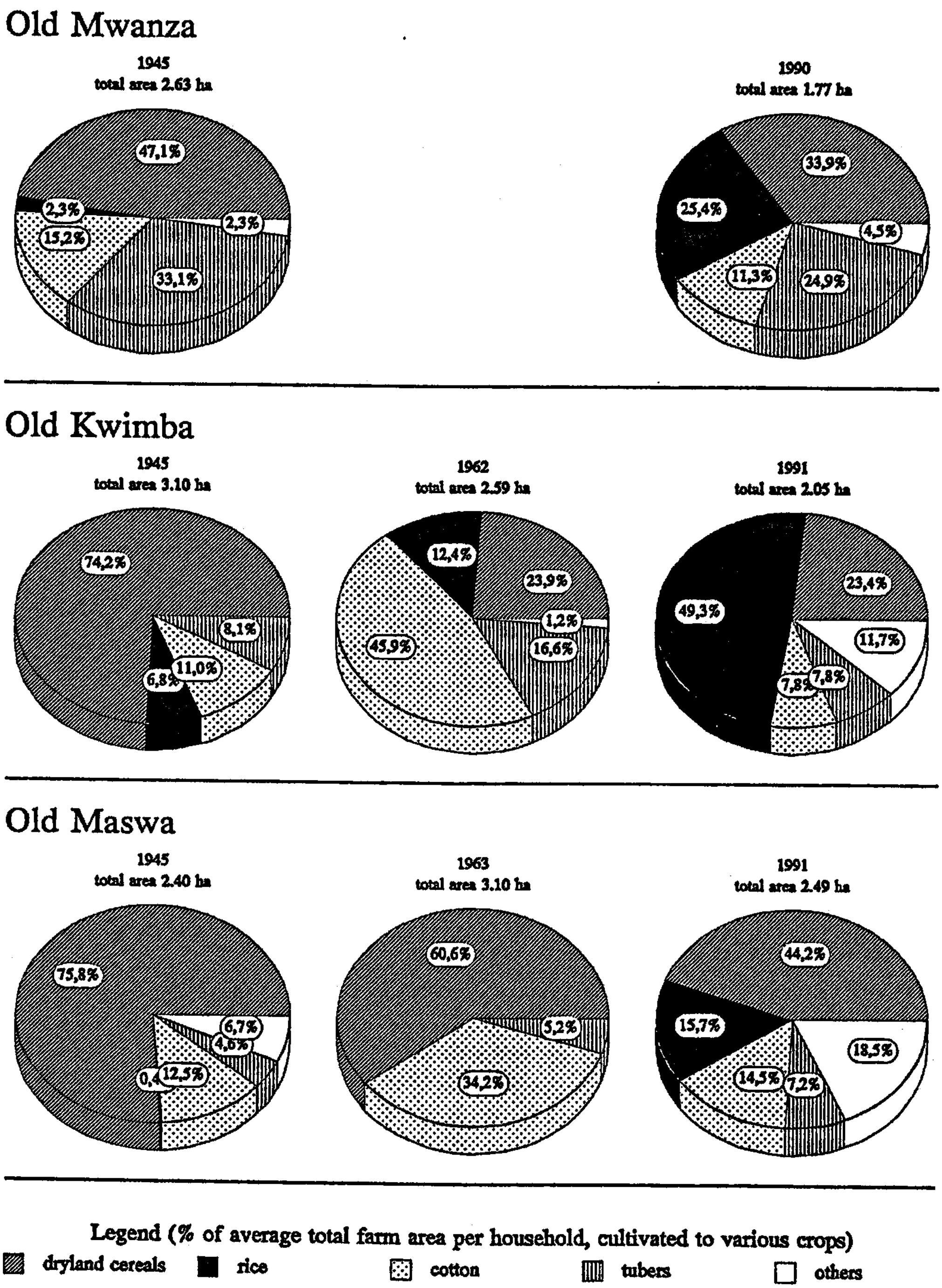
Sources: a Rounce (1949); b ICRA (1990); Meertens et al. (1995)

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

In contrast, the Sengerema Division of Old Kwimba is mainly located on a huge, almost flat plain dominated by hardpan soils. There are only a few sandy soils. Consequently, cassava is not important and sorghum is grown mainly as a food security crop. Following the increase in population density (Table 3.2) and the introduction of ox ploughs, the farmers expanded their rice areas on the hardpan clay soils at the expense of sorghum and maize. Initially, cotton competed with rice, but since the 1970s rice has been more profitable and by 1991 it had become the main food and cash crop for Sengerema Division.

The developments are again different for Old Maswa District, being a new

Fig. 3.5
Changes in the relative importance of the major crops grown by farm households in three districts of Sukumaland over the period 1945-1990. Dryland cereals include bulrush millet, sorghum and maize



settlement area from around 1945. At that time population density was only half that of Old Mwanza and Old Kwimba (Table 3.2). Because the grasslands in Mwanza and Kwimba could no longer support the increased number of animals, the cattle owners migrated to new grasslands that were recently freed from tsetse. Clayey soil types are dominant in Old Maswa and in 1945 the most important cereal was therefore sorghum and the main cash crop cotton. The relatively small total crop area at that time (Table 3.3) reflected the preoccupation of the households with livestock, as well as the fertility of the virgin land. Fig. 3.5 also shows that the cotton areas had increased more than threefold by 1963 because of the abundance of land and the introduction of oxploughs. The other major change was the partial replacement of sorghum by maize and rice as the preferred staple crops. The security and wealth generated by the cotton production stimulated farmers to grow maize instead of sorghum in spite of the drought risks. Yet, in the absence of cassava and bulrush millet, sorghum remained important as a security crop while the further expansion of rice is limited by the lack of suitable hardpan soils and the lower average annual rainfall (Fig. 3.2).

Livestock ownership

In Tanzania the word Sukuma is strongly associated with the ownership of many heads of cattle, the predominant race being the Tanzanian Shorthorn Zebu. The livestock population has indeed been increasing enormously following the rinderpest epidemic of 1891. By 1991 about half of the households owned livestock in almost every part of Sukumaland. However, the number of livestock units per household had decreased everywhere because of the increase in the total number of households (Table 3.3).

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

Intensification of land use

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

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

This development is mirrored in the yield trends for the different areas. While the rice and maize grain yields per hectare have doubled in Old Mwanza since 1945 (see Table 3.4) this trend does not occur in the other parts of Sukumaland where land is still relatively abundant.

Discussion and conclusions

Around 1945, Rounce (1949) estimated that 39 people per km^2 would be the optimum population density given the ecological conditions in Sukumaland. On this basis the 'overpopulated' areas were resettled at carefully controlled densities and new areas were opened up. Better farming methods like (green) manuring, mulching, erosion control, (tie-)ridging, pasture improvement, use of fodders and mechanization had to be adopted throughout Sukumaland to secure a sustainable agriculture.

By 1988, however, population densities, with the exception of Meatu, had become two to three times as high as the optimum calculated by Rounce (1949) (see Table 3.2). Moreover, almost all of the improved farming methods advocated by Rounce (1949) had been rejected by the farmers. Yet, even though the farming systems have remained relatively 'closed' with very limited use of external inputs, the predicted environmental disasters and famine have not occurred. It may be concluded that food production has kept pace with population growth, in spite of, or possibly because of, the considerable expansion of cotton; the latter holds if revenue from the cotton was used to purchase food.

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

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

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

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

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

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

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

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

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

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

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

The experiences of Rounce in Sukumaland, as well as those from many development projects elsewhere, demonstrate that technologies aimed at improving sustainability are readily rejected by farmers when not sufficiently relevant to the prevailing socio-economic conditions. This implies that farmers will adopt different types of technologies depending on the level of development and intensification of their farming system. For instance, only when all available fallow land is fully used do the incentives become sufficiently strong for a growing population to intensify its land-use. This is corroborated by the relatively advanced agricultural intensification around Mwanza town. The studies of Sukumaland and Machakos both show that rapid population growth in non-industrialized countries does not necessarily lead to irreversible land degradation and poverty. However, an understanding of the dynamics of agricultural production systems is necessary in developing relevant and acceptable policies and technologies aimed at improving the sustainability of the various land-use systems.

Notes

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

Acknowledgements

The authors wish to thank the entire FSR Lake Zone team and in particular H.J. Enserink of the Royal Tropical Institute (KIT) for sharing their knowledge of Sukumaland with us. The assistance of P. Penninkhoff (KIT) in improving the data presentation formats was much appreciated.

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4 The cultivation of rainfed, lowland rice in Sukumaland, Tanzania**

Abstract: Recent agricultural surveys conducted in Sukumaland, Tanzania, drew attention to the importance of rainfed, lowland rice in the studied farming systems. Information from these surveys is used to provide the first detailed description of rice cultivation in Sukumaland. Such a description is needed for a better understanding of the level of importance, the current performance, and the future possibilities of this rice cultivation system.

More than a third of rice produced in Tanzania comes from Sukumaland. Farmers increased their rice production quickly when rice cultivation became more profitable in comparison to cotton and other crops. Smaller farm sizes because of increasing population densities also made rice more popular as a food crop, because of its capability to produce high amounts of calories on small pieces of land. Farmers' innovations, experimentations and agricultural knowledge developed this bunded rainfed lowland rice system in Sukumaland as a way to secure the sustainability of their farming systems. It turned a semi-arid environment into a rice exporting area. Rice management practices follow closely differences in ecology and household characteristics. Selection of rice cultivars is largely determined by water conditions in the field.

Future research and extension on rainfed lowland rice in Sukumaland as well as in other parts of Tanzania and Africa will benefit from a proper description of rice cultivation, which includes farmers' knowledge and diversity at the level of household, rice valley and rice field.

Keywords: Rainfed lowland rice, Farmers' knowledge, Sustainability, Tanzania

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** Accepted for publication in *Agriculture, Ecosystems & Environment*

Introduction

According to Carpenter (1978), the first appearance on the East African coast of *Oryza sativa* types of rice may have resulted from traders from Sri Lanka and India sailing via Oman to Somalia, Zanzibar and Kilwa some 2000 years ago. Penetration of *Oryza sativa* into the hinterlands of Africa was along the slave trading routes from the East African coast and Zanzibar to Zaire during the nineteenth century. The area inhabited by the Wanyamwezi in central Tanzania became the inland base of the traders from 1852 onwards (Iliffe, 1979). From the headquarters at Tabora one route led to neighbouring Sukumaland, the area inhabited by the Wasukuma, bordering Lake Victoria in northwestern Tanzania. Formerly unknown crops such as maize, cassava and rice were carried along the caravan routes to supplement the local diet of millet, sorghum and banana. The cultivation of rice was generally started by Arab traders who settled in these areas. The local farmers were initially not much interested in this new crop because its production turned out to be less reliable in comparison with millet and sorghum.

British colonial agricultural officers observed in the 1930s that the cultivation of *indica* rice had slowly increased in Sukumaland since its introduction, and that in some parts it had even become the most important cash crop. They noted that farmers constructed small bunds around the rice fields in the valleys to catch rainwater and surfacing groundwater from higher situated areas (Thornton and Allnut, 1949). However, the production of rice decreased between 1936 and 1956, and in 1956 it was decided that there was no justification for further research on rice improvement (Doggett, 1965). The cultivation of rice in Sukumaland was not stimulated during the 1960s, 1970s and 1980s, because the Tanzanian government regarded Sukumaland as a semi-arid environment suited only for drought tolerant crops such as cassava, sorghum and cotton (Meertens et al., 1995). Notwithstanding the government regulations and extension officers' instructions, rice cultivation increased tremendously in Sukumaland during the 1970s and 1980s. Official data show that Sukumaland, consisting of Mwanza and Shinyanga regions (Fig. 4.1), produced 35% of the total Tanzanian rice production during 1985-95 (Mdadila, 1998). Recent surveys conducted in Mwanza and Shinyanga regions (Mashaka et al., 1992; Meertens and Lupeja, 1996) point to even higher production levels and areas of rainfed lowland rice than the official figures.

The rise in rice production was connected to the decline in cotton production between 1967 and 1986; the period when Tanzania followed a socialist strategy. The production of cotton increased enormously in Sukumaland during the 50s and early 60s because of high world market prices, improved cotton organization, marketing and research, and the local migration of many Wasukuma to favourable areas for cotton cultivation. The higher profitability of cotton and the competition for labour between cotton and rice blocked the development of rice during that period. Farmers preferred to grow the less labour consuming crops sorghum, bulrush millet and cassava for food, in addition to cotton. The Tanzanian government controlled every aspect of cotton marketing during the socialist period. Inefficiency in government cotton marketing seriously decreased the producer share of the world market price. Embezzlements at the marketing boards or cooperatives left cotton farmers without any payment in several years. Thus, these farmers abandoned the cultivation of cotton massively and switched to rice and maize as alternative cash crops wherever this was possible. After 1986 when Tanzania followed structural changes from the World Bank and IMF there were some improvements in the cotton sector. Farmers in the drier parts of Sukumaland returned to cotton whenever there was a substantial increase in the producer price of seed cotton. In the areas with high potential for rice and maize there was, however, only a modest return to cotton (Meertens et al., 1995).

The focus of government agricultural institutions (research, extension) on cotton, cassava and sorghum left the increase in rice production almost unnoticed. However, recent agricultural surveys conducted in Sukumaland (FSR Project Lake Zone, 1989 and 1994; ICRA, 1990 and 1991; Mashaka et al., 1992; Meertens and Ndege, 1993; Meertens and Lupeja, 1996) drew attention to the importance of rice in many parts of Mwanza and Shinyanga regions. This paper is a synthesis of information on rice cultivation from the above mentioned agricultural surveys. It shows how farmers' innovations created a rainfed lowland rice system under adverse climatic and governmental support conditions as a response to market forces and as a way to secure the sustainability of their farming systems. This first detailed description of rice cultivation in Sukumaland should help to shape future research and extension on rainfed lowland rice in Tanzania and other parts of Africa.

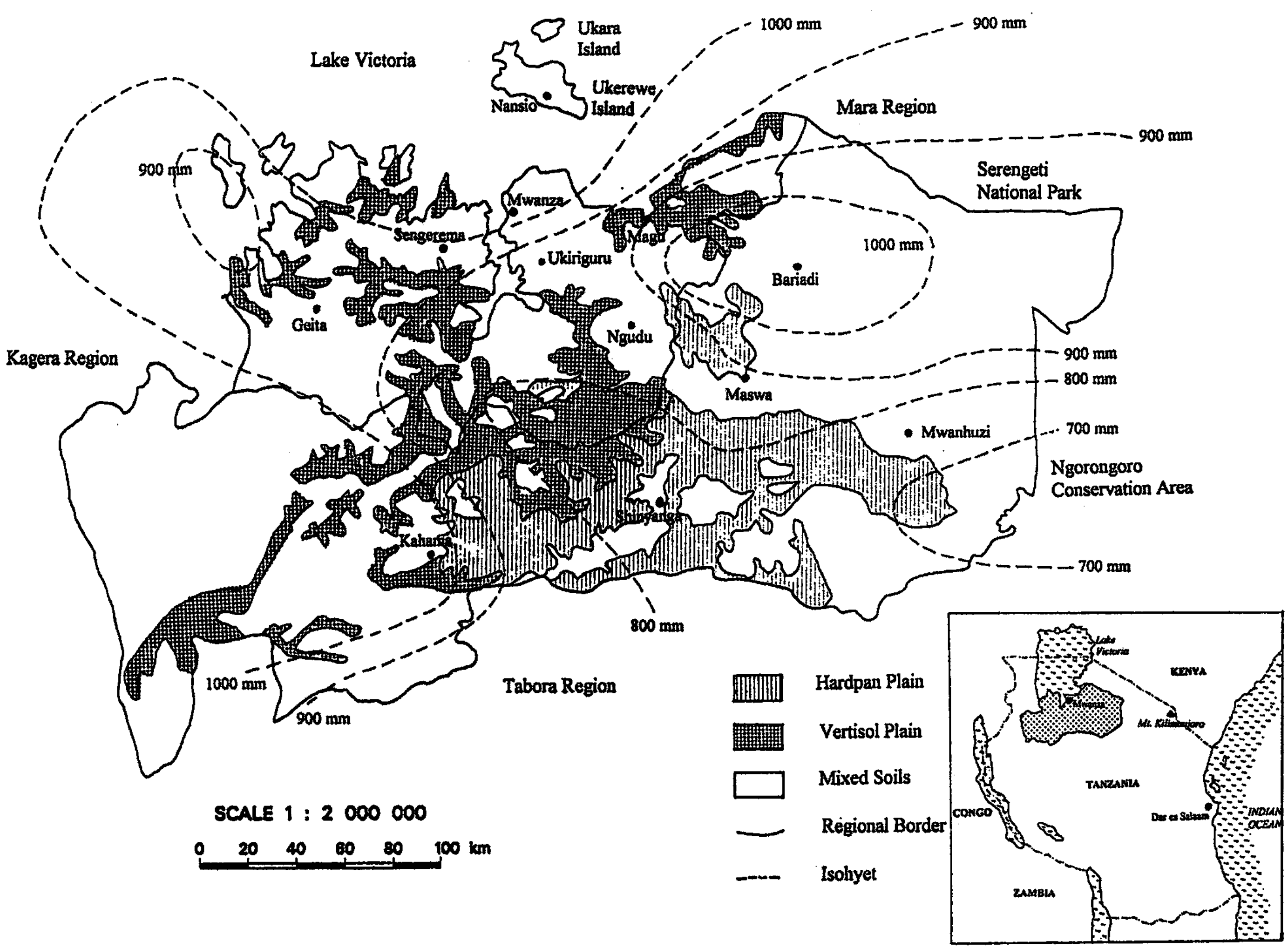
Characterization of rice cropping systems in Sukumaland

General characteristics

The system of rice cultivation in Sukumaland can generally be classified as rainfed lowland rice, i.e. rice grown on non-irrigated (bunded) fields that are flooded for at least part of the cropping season at water depths that do not exceed 50 cm for more than 10 consecutive days. Rainfed lowland rice accounts for 29% of the world's rice and 19% of the global rice supply (Fujisaka, 1990). In Tanzania 74% of the total rice area is rainfed lowland rice, 20% is upland rice, and 6% is irrigated rice (Kanyeka et al., 1994). Recent descriptions of rainfed lowland rice in Cambodia (Lando and Mak, 1994), Laos, Nepal, Thailand and Madagascar (Fujisaka, 1990) show that the main management practices do not differ from the ones in Sukumaland. In Sukumaland the construction of bunds is essential for rainfed lowland rice on slopes in order to catch and control the uncertain water supply because of highly unreliable rainfall and relatively low total annual amount of rainfall (700-1000 mm). The only exceptions are rice fields in floodplains near rivers which receive water from floods (Enserink et al., 1994). This so called unbunded, flooded rainfed lowland rice system is more common in other parts of Tanzania (Kanyeka et al., 1994).

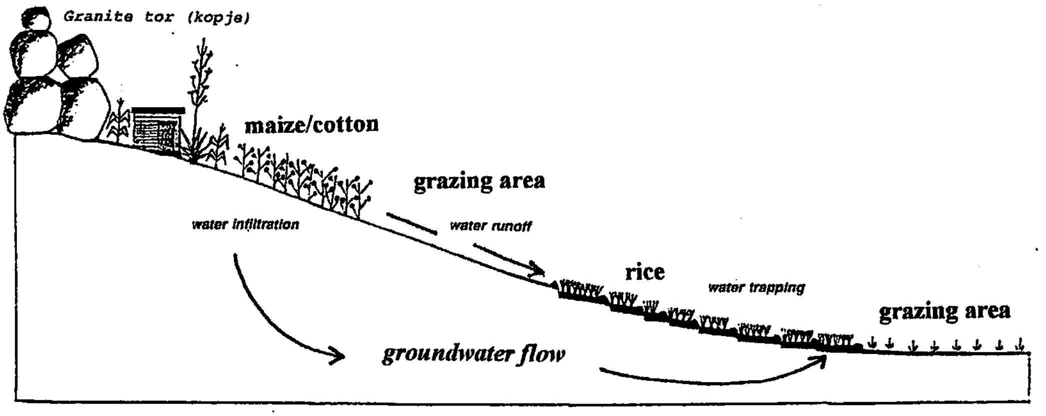
In Sukumaland rains start around mid-October and end around mid-May. The pattern is bimodal with peaks in November-December and March-April. The rainshowers are very localized and unpredictable. Dry spells are common throughout the rainy season but are more pronounced during January. Potential evapotranspiration rates of 4.5 mm day^{-1} occur during the rainy season (ICRA, 1991). According to the water balance classification of Garrity et al. (1986), which is based on water retention potential (slope, soil texture) and rainfall regime (amount of rainfall and length of growing season), the rainfed lowland rice system in Sukumaland is drought-prone. The landscape in Mwanza region is dominated by broad and narrow valleys separated by rocky hills consisting mainly of granitic and sometimes gneissic rocks. The landscape in Shinyanga region is characterized by vast

Fig. 4.1
Dominant soils and rainfall patterns in Sukumland



Source: based on De Pauw (1984); Van der Linde et al. (1995); Bantje (1991)

Fig. 4.2
Trapping of water for rainfed lowland rice cultivation on the hardpan plain in Maswa district, Sukumaland



Source: based on Ngailo et al., 1994

fluvial and lacustrine plains derived from the same type of rocks (Meertens et al., 1996). The majority of plains in Sukumaland have slopes of between 0 and 8% (De Pauw, 1984). Fig. 4.2 shows how water from higher elevated areas through lateral flow of runoff and groundwater accumulates in the lower situated rice fields. These rice fields are often located on loamy soils (*itogolo/ibambasi*) with a hardpan horizon less than 50 cm below the surface, resulting in low infiltration of water. According to Milne (1947), the hardpan horizon is an illuvial concentration of clay. The heavy clay soils (vertisols, *mbuga)* in the valley bottoms also have low infiltration rates whenever they are flooded.

Differences according to local circumstances

The variations in soils and average annual rainfall combined with variations in population density have led to a number of farming systems in Sukumaland. The importance and type of rice cultivation differs among these farming systems (Meertens et al., 1995). Apart from hardpan soils and heavy clay soils there are also vast areas dominated by other soil types. In relation to the importance of rice, it is better to classify all those areas other than hardpan- and vertisol plains together into one group of mixed soils (Fig. 4.1). In this group of mixed soils, rice cultivation can be locally important when the area is characterized by long slopes. The proportion of hardpan soils increases on long slopes because sedimentation and illuviation of clay particles occurs here on a greater section of the slope. In various parts of Sukumaland this appears to be the case. Unfortunately there are no maps with detailed information about the length of slopes so that it was not possible to mark the areas with higher proportions of hardpan soils.

Fig. 4.1 shows the dominance of certain soil types in relation to average annual rainfall. It appears that huge parts of hardpan plains near Shinyanga and Mwanhuzi towns are receiving suboptimal amounts of annual rainfall (less than 800 mm) for rainfed lowland rice cultivation. Only the hardpan plains near Maswa and Kahama towns receive more than 900 mm annual rainfall. A relatively greater part of the vertisol plains is situated in the higher rainfall zones. Because of the flat character of these plains there is, however, not enough accumulation of water for the cultivation of rice and most of these plains are instead used for the cultivation of maize, cotton and chickpeas. Only the vertisol plains near rivers are mainly planted with rice in years with floods. Most parts of the remaining group of mixed soils receive sufficient rainfall for rice cultivation. In combination with long slopes these form high potential zones for rice cultivation.

In contrast to vertisol plains, hardpan plains are not completely flat, but very gently undulating with an overall slope of 0-1%. Because of the long slope of the valleys and the dominance of hardpan soils, large amounts of water can accumulate through runoff. On the Maswa hardpan plain it was further observed that soils halfway the slope were kept bare intentionally by grazing (Fig. 4.2). After the first rains these bare soils develop surface crusts which reduce infiltration and maximize runoff to the rice fields (Ngailo et al., 1994). This technique is, however, disappearing because of the growing popularity of rice cultivation and the increases in population density. The profitability of rice growing encouraged an increasing number of households to cultivate rice on higher and lower parts of valley slopes. Former grazing areas and bare slope segments are now transformed into rice fields. The above described technique is nowhere to be seen in the rice valleys close to Lake Victoria and on the islands. Population densities there range between 100 and 270 people per km^2 (Meertens and Lupeja, 1996) whereas there are 30-75 people per km^2 in the rest of Sukumaland (Meertens et al., 1996). The much higher population densities make it impossible to keep large areas for grazing and have reduced strongly or eliminated completely the amount of fallow land.

Next to the main classifications according to dominant soils, annual rainfall and type of slope valleys can further be differentiated according to their water catchment areas. The potential amount of water that may accumulate in the valley bottom not only depends on the length and slope of the valley, but also on the width of the valley at the top and the bottom. The potential amount of water that may accumulate in the rice fields is high when the width of the valley bottom is small in comparison with the valley width at the top. When all these parameters are taken into consideration, a detailed classification of valleys could be made, similar to that done by Windmeijer et al. (1994) for parts of Ivory Coast. For Sukumaland such a detailed classification of valleys has limited use because of the highly unpredictable rainfall and the very localized nature of rainshowers. A valley with a small catchment area can become more productive than valleys with large catchment areas because of the receipt of heavy showers at the right time and place.

Rice management practices

Land preparation

Some households decide to make new rice fields through the construction of bunds at the end of the rainy season (April/May), when the soils are still moist and workable. For rice fields located in valleys with large catchment areas the bunds have to be high and wide. The construction of bunds is accompanied with levelling of the new fields to assure an even distribution of water. For already established rice fields, people first manually remove weeds with strong thorns, *samang'ombe* (*Hygrophila spinosa*), and burn them in the field. They then repair the bunds and repeat the levelling exercise after the first rains in October and November.

Normally land preparation starts in November but unfavourable rainfall can postpone it till January/February. In Sukumaland farmers' use of tractors is very limited and instead they use ox ploughs or hand hoes for preparing the rice fields. A survey among 65 households on the Maswa hardpan plain showed that 78% were using ox plough and 22% hand hoe for land preparation (Meertens and Ndege, 1993). In this less densely populated part of Sukumaland many households have access to an ox plough which enables them to prepare on time large areas of difficult clayey soils. In the more densely populated parts of Sukumaland, fewer farmers have access to an ox plough, and thus, most farmers prepare smaller rice areas by hand hoe. Some farmers with ox plough prepare the rice fields a second time to plough under already germinated weeds. In this way incorporated weeds serve as a green manure and competition is reduced for the young rice plants.

Crop establishment

Rice is planted in two different ways in Sukumaland. In the areas with lower population densities (Shinyanga region and southern Mwanza region), farmers mainly use the extensive dry seeding method on wet soils common in large parts of India (Garrity et al., 1986). Rice seeds are broadcast sown just before land preparation, allowing relatively large areas to be sown in a short period. In the densely populated areas, farmers use the intensive method of transplanting seedlings from nurseries to relatively small rice fields. A combination of these two methods uses broadcast fields partially as nurseries for transplanted fields. This is done by broadcasting large amounts of seeds on fields located in the upper parts of the slope. These fields are the first to receive runoff water and cannot become flooded unlike the lower situated fields. With good germination rates, the excess seedlings are thinned and transplanted to the lower fields when these have favourable water depths. In the more densely populated areas of Sukumaland, nurseries are established in a corner or strip of a field located in the upper parts of the slope. Good environments for nurseries are seepage zones, which occur often in areas with steeper slopes.

Transplanting is usually done in December, January and February, but unfavourable rainfall can postpone this practice until the end of March. Farmers on the Maswa hardpan plain regard a water depth just above 15 cm ideal for transplanting (Meertens and Ndege, 1993). Lower water depths are risky as transplanting can be followed by serious dry spells. Higher water depths reduce tillering and give poor results when floods wash away the poorly anchored seedlings. Before transplanting, fields are puddled by hand hoe so that seedlings can easily be put in the mud. During this exercise weeds are removed and incorporated in the mud.

Very few farmers plant rice in lines. In the broadcast as well as the transplanted fields farmers do, however, aim at a certain plant density. The approximate spacing depends on fertility of the soil, cultivar, water circumstances of the field and total rice area of a household. Heavy tillering cultivars in fertile valley bottoms are wider spaced than slightly tillering cultivars in upper, sandy fields. Households with small rice areas use closer spacings in their fields. The average spacing over all cultivars on the Maswa hardpan plain was 22.5 cm by 22.5 cm with one plant per hill (Meertens and Ndege, 1993). Plant density measurements in the more populated parts of Mwanza region (Lupeja and Meertens, 1996b) showed that the average spacing was 19 cm by 19 cm with one plant per hill.

Rice cultivars

Cultivars used in Sukumaland belong to the *indica* sub-species of *Oryza sativa*. All these cultivars are tall, sensitive to photoperiod and possess aromatic grains (IRRI, 1985). Farmers have introduced many different cultivars from other parts of Tanzania, with origins from all over the world in Sukumaland (Table 4.1). Examples are 'Faya' from Malawi, 'Sindano' from Kenya and 'Sokotera' from Zanzibar (Virmani et al., 1978). 'Tondogoso' was said to originate from the coastal areas of Tanzania, 'Super', also known as 'Supa India' or 'Turiani', was brought from Morogoro region (Meertens and Ndege, 1993). The long-grained, aromatic *Super* originated from 'Surinam V-880' from Surinam in South America (IRRI, 1985), and today is the most important cultivar in Sukumaland. Almost half of the rice fields on the Maswa hardpan plain were planted in 1990/91 with this cultivar (Meertens and Ndege, 1993), and a survey covering twelve villages in Mwanza region showed that this cultivar was preferred by farmers in eleven villages (Meertens and Lupeja, 1996). *Super* in comparison with other cultivars, needs less water for its growth, and, thus can better withstand the frequent dry spells in Sukumaland. *Super* has also a good taste and a good price on the market next to a satisfactory production.

Table 4.1
The most important rice cultivars in Sukumaland during the 1990s

Cultivar	Tillering Capacity	Water Requirement	Other Characteristics
Super	Low	Low	Good taste, early maturing, good price
Rangi mbili	Low	Medium	Early maturing, withstands some drought
Pishauri	Low	Low	Early maturing, withstands some drought
Sindano	Low	Low	Less damage from birds
Faya	Medium	Medium	High production, good taste
Kahogo	Medium	Medium	Good taste, less damage from birds
Tondogoso	High	High	High production, good for porridge
Lugata	High	High	Good for porridge, heavy seeds

Sources: Meertens and Ndege (1993); Meertens and Lupeja (1996)

All cultivars with low or medium water requirements (Table 4.1) are important rice cultivars in Mwanza region. Population growth here caused an increase in rice cultivation on the higher, more sandy parts of slopes. On these more sandy soils water remains for shorter periods because of higher percolation rates. Low water depths are more frequent under such circumstances. Cultivars with high water requirements, e.g. *Tondogoso* and 'Lugata', are popular in the valley bottoms and on the hardpan plains. Cultivars with awns on the spikelets such as 'Kahogo' and *Sindano* are less susceptible to damage from birds (Meertens and Ndege, 1993).

Farmers experiment with new cultivars and discover that some cultivars perform better under certain circumstances than their usual cultivars. Choice of cultivar is strongly connected to the water circumstances of a field. As mentioned water circumstances differ according to variations in soils, location on the slope, size of catchment area, rainfall pattern and the proportion of rice cultivation to the length of the slope. In Cambodia farmers use a large range of cultivars adapted to various soils and water circumstances (Lando and Mak, 1994). The same applies to rainfed lowland rice cultivation in Sierra Leone where 25-50 different cultivars are used in one village to match the variation in soil moisture conditions (Richards, 1985). In Madagascar, Nepal, Thailand, Laos and Cambodia individual farmers plant three to six different cultivars to match the variations in land, soil and water conditions in their rainfed lowland rice systems (Fujisaka, 1990). In the Mwanza region, almost 40 different cultivars were recorded in a recent survey (Meertens and Lupeja, 1996).

Weeding

Weed infestations depend on method, quality and number of land preparations, type of soil, and most importantly, the water regime in a field. A permanent, sufficient, water depth after broadcasting or transplanting eliminates weeds which can not grow in water. When fields stay dry for too long a time, weeds start to grow faster than the rice plants. Under such circumstances, farmers may not weed because the clayey soils are too hard to handle with a hand hoe. Only the arrival of water in the field can solve this problem. On the Maswa hardpan plain farmers normally have to weed their broadcast fields one or two times per season (Meertens and Ndege, 1993). Observations in more populated parts of Mwanza region showed that most farmers had to weed their transplanted fields only once after puddling (Lupeja and Meertens, 1996a). Farmers regard *Echinocloa colona, Sphenoclea zeylanica, Monochoria vaginalis, Hygrophila spinosa* and *Cyperaceae* as the most troublesome weeds. Other, less difficult or less widespread weeds are wild rice cultivars (*Oryza longistaminata, Oryza punctata*), *Digitaria scalarum, Commelina benghalensis, Corchorus olitorius, Ludwigia hyssopifolia* and *Jussiea suffructicosa.*

Harvesting

Harvesting of rice fields in Sukumaland starts in April and continues to the end of July. The large variation in harvest dates is caused by variation in maturation of cultivars (145-175 days), water conditions in the fields, and labour available to households for land preparation, transplanting, weeding and harvesting. Delaying the harvest increases the shedding of seeds, especially of the 'Rangi mbili' and *Kahogo* cultivars, from lodging and senescence of rice plants. It also decreases the quality of the seeds. Late rains can cause damage when fungi develop on wet seeds which remain in the fields. Too long drying periods in the fields make the seeds so dry that they easily crack during milling. Most households harvest their rice by cutting each head separately with a knife. Others prefer the less laborious method of cutting the entire plant at the base with a sickle. This latter method necessitates threshing in or near rice fields, which increases the loss of seeds and the amount of sand mixed in with rice.

Rice yields differ according to varying water circumstances in the fields during the season. Timeliness of field operations, rice cultivar, type of soil, degree of weed infestation and the intensity of the cultivation (broadcasting/transplanting) also affect the yield level. On the Maswa hardpan plain the average rice yield for the normal 1990/91 season was about 2800 kg ha^{-1} (Meertens and Ndege, 1993). Farmers in twelve villages spread over Mwanza region stated that the average rice yield covering bad, normal and good seasons is about 2300 kg ha^{-1} (Meertens and Lupeja, 1996). In bad seasons, rice yields mostly vary between 500 and 2000 kg ha^{-1}, and many fields are left to fallow because of drought. During good seasons, rice yields are between 3000 and 4000 kg ha^{-1}. Thus local cultivars can reach high yield levels with favourable water circumstances despite the fact that farmers use almost no farmyard manure, fertilizers, insecticides and herbicides. The relatively high yields also indicate that most rice fields in Sukumaland as yet still possess a satisfactory natural fertility. Despite better water conditions average rainfed lowland rice yields in Cambodia appeared to be only 1650 kg ha^{-1} because of poor natural fertility of the acidic sandy loam soils from prolonged and continuous cultivation (Lando and Mak, 1994). Reported average yields from farmers' rainfed lowland rice fields in Madagascar, Nepal, Thailand, Laos and Cambodia are generally less than 2000 kg ha^{-1} (Fujisaka, 1990).

Importance of rice in the farming systems

In the beginning of the 1960s, farm management surveys conducted in several parts of Sukumaland showed that the cultivation of cotton gave higher returns to labour than rice (Collinson, 1963 and 1965). This changed when the producer share of the world market price for cotton decreased continuously during the socialist period (1967-1986) in Tanzania. The cultivation of rice, maize, tomatoes and chickpeas became more profitable in areas receiving more than 800 mm annual rainfall (Meertens et al., 1995). In contrast to cotton, producer prices for rice remained high on the open markets because of high demands for Sukumaland rice in Zanzibar, Uganda, Rwanda, Burundi, Kenya and Mwanza town. In the past two decades there has been a large increase in the demand for rice in Africa's rapidly growing cities, where rice is increasingly becoming the staple diet of many urban households (Adesina and Gaye, 1993). In the more densely populated parts of Sukumaland rice also became a more important food crop, because of its capacity to produce high amounts of calories on relatively small pieces of land. Generally, the proportion of land assigned to rice has increased steadily in all parts of Sukumaland between 1945 and 1990 (Meertens et al., 1996).

Variations in importance arising from local circumstances

The importance of rice varies because of differences in annual rainfall, population density, dominant soil type and nature of the season. Table 4.2 shows the proportion of cultivated land devoted to rice in Sukumaland according to type of soil and season. Rice occupies more than half of the total cultivated area for households on the Maswa hardpan plain in an average season (Table 4.2). This percentage is less for households on vertisol plains or on mixed soils in Mwanza region even in wet seasons. Table 4.2 shows that the importance of rice is highest on the hardpan plains and lowest on the vertisol plains while areas with mixed soils taking a medium position.

The proportion of land assigned to rice fluctuates strongly in Sukumaland between dry and wet years. When rainfall is insufficient many households fail to cultivate rice because only very few farmers have access to small-scale irrigation. The greatest differences between wet and dry years occur on the vertisol plains (Table 4.2). In dry seasons there are almost no fields with standing water on these plains but in wet seasons large parts are flooded and fit for rice cultivation.

Differentiation according to households

The role of rice in each farming system varies further according to type of household. Households differ in their access to land, labour and capital and this affects the cultivation of rice in many aspects. The survey on the Maswa hardpan plain revealed the interaction between access to an ox plough, rice acreage, method of cultivation, labour force, cattle ownership and the importance of rice for a household (Meertens and Ndege, 1993). Fig. 4.3 shows some of these correlations. Households owning an ox plough have a much larger acreage of rice and many more units of labour and cattle than the other households. Households with oxen and plough started to cultivate rice on the clayey soils in the valleys and could increase their rice acreage easily during the heyday of cotton. With the help of ploughs and oxen, they are able to prepare large areas of land for rice cultivation in a short time at the start of the season. The production from these large rice acreages surpasses the consumption needs of these families and enables them to sell the remaining rice. With the sale of the substantial surplusses the families are then able to use even more land, labour and cattle in the following season.

The other households own less and more marginal, scattered rice acreages. About one out of ten households in Maswa has to rent all their rice fields (Meertens and Ndege, 1993). One third of the total rice production per household was estimated to be the average surplus beyond household needs in Maswa district and Mwanza region (Meertens and Ndege, 1993; Meertens and Lupeja, 1996). After deductions for bartering rice for maize and for storage of rice for future consumption and next season's planting, about one quarter of the total rice production per household remained for selling to traders in Maswa district (Meertens and Ndege, 1993).

Hiring or borrowing an ox plough delays the land preparation because the owner uses the ox plough first for all his own fields. Preparing the land by hand hoe is very laborious and restricts the total size of the rice acreage. In the Maswa survey, 32% of households owned an ox plough, 32% hired it, 14% borrowed it and 22% used solely the hand hoe. Households without ox plough transplant a higher proportion of their rice acreage than households with ox plough (Fig. 4.3). This can be a compensation for the smaller rice area or a result of the delay during land preparation. Transplanting is, however, more laborious. Households without ox plough are able to transplant relatively more because of their higher labour to land ratio (Fig. 4.3). Fig. 4.4 gives the estimated labour requirements for a broadcast or transplanted hectare of rice by ox plough or hand hoe on the Maswa hardpan plain.

Table 4.2
Proportion of cultivated land devoted to rice in Sukumaland according to variations in soils and seasons

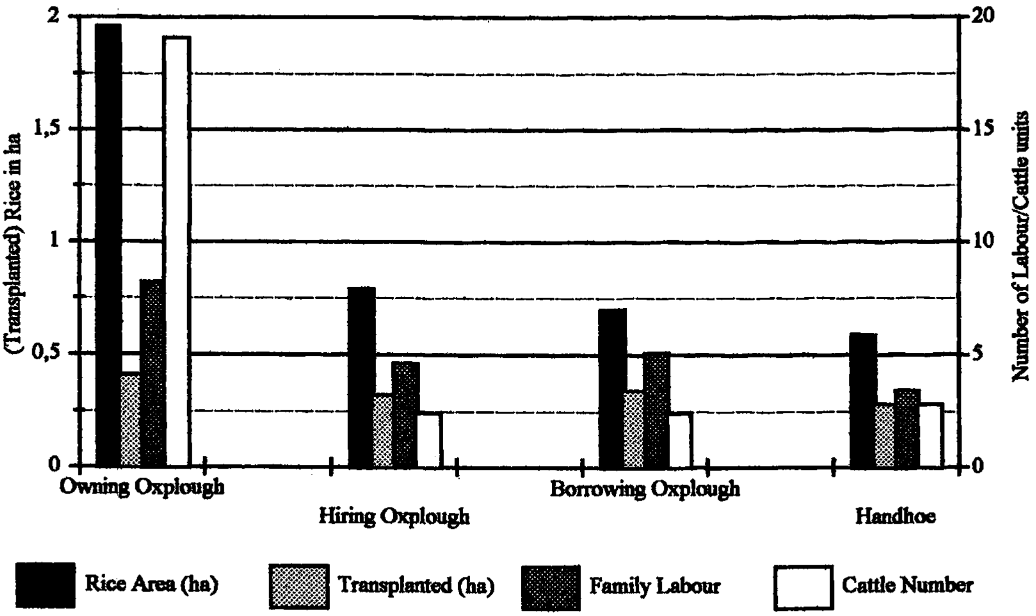
	Av. total cultivated area per household (ha)	Av. cultivated rice area per household (ha)			Percentage of cultivated land devoted to rice		
Season		Average	Dry	Wet	Average	Dry	Wet
Hardpan Plain Maswa District (65 households)	1.9	1.1			58%		
Vertisol Plains Mwanza Region (110 households)	3.0		0.15	0.83		5%	28%
Mixed Soils Mwanza Region (330 households)	2.2		0.39	0.81		18%	37%

Sources: based on Meertens and Ndege (1993) and Meertens and Lupeja (1996)

Broadcasting rice on land prepared by ox plough requires 210 labour days ha^{-1} and transplanting rice on land prepared by hand hoe 269 labour days ha^{-1} (Fig. 4.4). These labour requirements are comparable with the 217 labour days ha^{-1} for unbunded rainfed lowland rice cultivation in Morogoro region and the 244 labour days ha^{-1} for rainfed upland rice cultivation in Kyela district, Mbeya region (Mdadila, 1998). Households on the Maswa hardpan plain are devoting, in addition to half of their land, half of the total available family labour to the cultivation of rice (Meertens and Ndege, 1993). Both men and women are fully involved in the cultivation of rice because it is an important cash as well as food crop.

Because each head is harvested separately, harvesting is time consuming (Fig. 4.4). An average of 126 labour days ha^{-1} were used for harvesting 2.8 tonnes rice on the Maswa hardpan plain. This figure corresponds with 45 labour days ha^{-1} for harvesting one tonne of rice. In Cambodia, Laos, Madagascar and Nepal farmers used only between 11 and 27.5 labour days ha^{-1} for harvesting one tonne of rice. In all these countries there was less need for weeding, no need for birdscaring and so total labour inputs varied between 100 and 200 labour days ha^{-1} only (Fujisaka, 1990). The family labour force is often not sufficient for harvesting rice in Sukumaland. In order to avoid harvest losses households have to add labour from other sources. Half of the households on the Maswa hardpan plain, especially the ox plough-owners, used for that task communal workgroups (Meertens and Ndege, 1993). These are groups of neighbours who are supplied with food. One family member has to join the workgroup on the fields of the neighbours. This so called *buyobe* system is, however, not an option for poor households with very few family members (often female headed

Fig. 4.3
Rice area, family labour force and cattle ownership for households with different access to ox plough on the hardpan plain of Maswa district



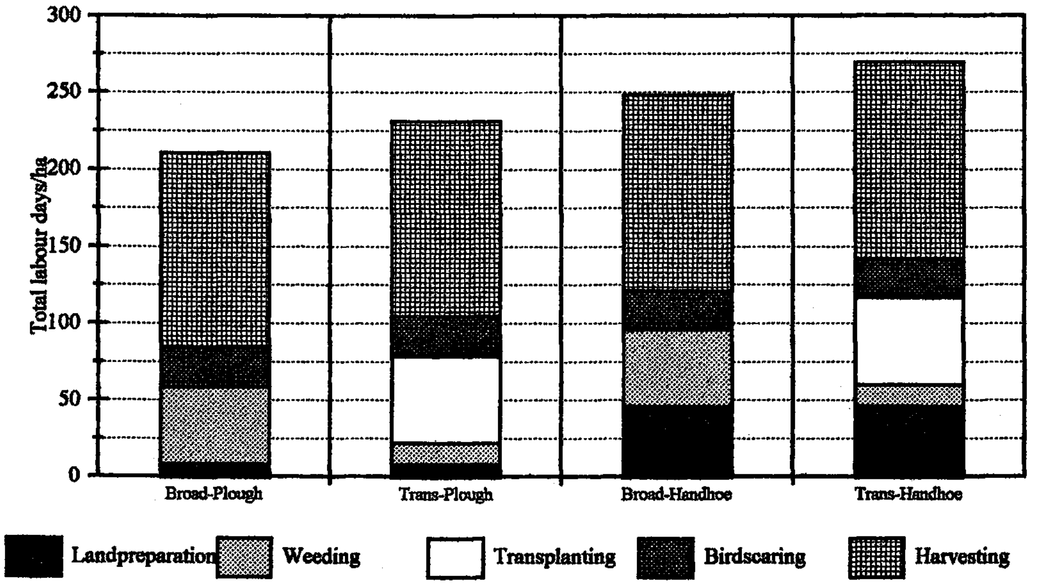
Source: based on Meertens and Ndege, 1993

households) because they can neither supply the food nor a member to the workgroup. Only few households contract hired labourers to add labour. These hired labourers are often members of poor families who urgently need some cash. Households which borrow an ox plough assist the ox plough owners with their land preparation in exchange for the ox plough.
In general the diversity at the level of household, rice field and rice yield resembles the variation in cotton and sorghum cultivation by farmers in northern Cameroon (Steenhuijsen Piters, 1995).

Constraints to rice production

The households on the Maswa hardpan plain regard weeds as the most important constraint in rice cultivation. As explained previously, this problem is directly connected to water availability. Problems with water ranked second on the list of main constraints, followed by stemborers and labour for tasks other than weeding (Meertens and Ndege, 1993). The survey in Mwanza region also revealed that farmers consider weeds to be the main problem in rice cultivation. Other important constraints in rice production for farmers in Mwanza region were high prices and poor availability of agricultural inputs, damage from birds, low soil fertility and stemborers (Meertens and Lupeja, 1996).

Fig. 4.4
Labour requirements in labour days ha^{-1} for broadcast or transplanted rice by ox plough or hand hoe on the hardpan plain in Maswa district



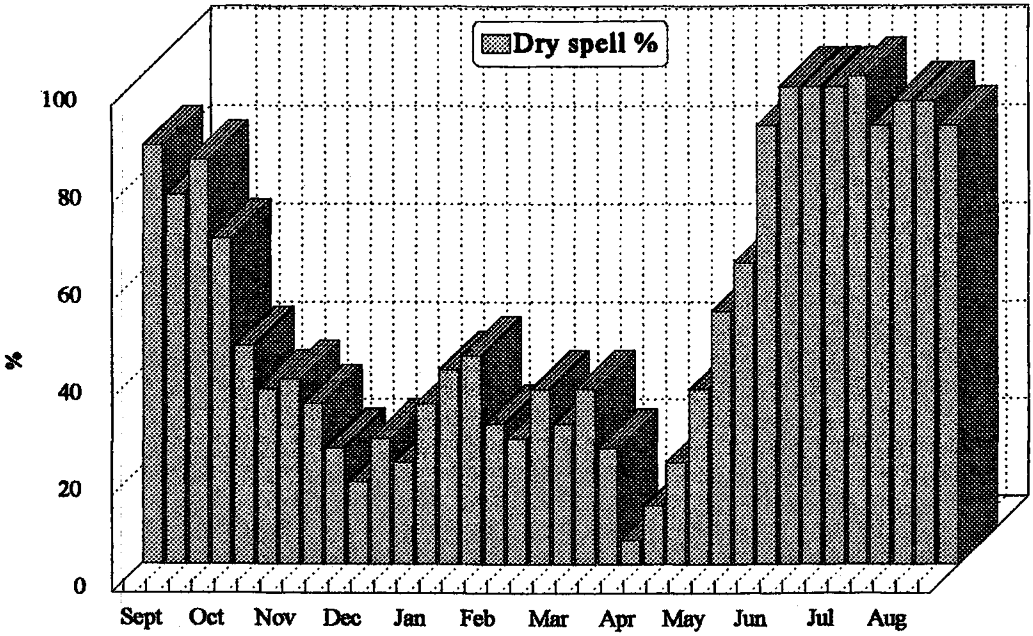
	Broadcast-Plough	Transplanted-Plough	Broadcast-Handhoe	Transplanted-Handhoe
Landpreparation	9	9	48	48
Weeding	50	13	50	13
Transplanting	0	57	0	57
Birdscaring	25	25	25	25
Harvesting	126	126	126	126
Total labour days/ha	210	230	249	269

Source: based on Meertens and Ndege, 1993

Weeds and water problems

Weeds are considered to be the main problem in broadcast and transplanted rice fields, although harvesting and transplanting require more labour (Fig. 4.4). Weeding has to be done, however, during the height of the season when all households are busy in their own fields. Few families are then able to supply people to communal workgroups. This is also the period when most households have cash constraints and hired labourers are very expensive. So weeding has to be performed by family labour only. In case of heavy weeds infestations, households fail to weed their rice fields properly, and this seriously affects yield. In Asia farmers use hand-pushed devices to remove weeds mechanically in between the lines. In Sukumaland this system could

Fig. 4.5
Probability of a dry spell per ten days (< 15 mm in 10 days) at Ukiriguru Agricultural Research Institute as a percentage over 42 seasons (1953-1995)



Source: Meertens and Lupeja, 1996 (on the basis of data supplied by Meteorological Department of Ukiriguru A.R.I.)

only be used if farmers started to plant their rice in lines. The best method to reduce the problem of weeds is to have a permanent, high water depth in the fields so that most types of weeds fail to develop. Dry spells are, however, common throughout the year, even during the rainy season from October to May (Fig. 4.5). During prolonged dry spells rice fields can become completely dry leading to serious weed infestations. Furthermore the hard, dried out, clayey soils make weeding with hand hoes almost impossible.

Prolonged dry spells at other stages of the season can lead to delayed or improper land preparation, broadcasting and transplanting, all of which substantially decrease the production of rice. In some years rainfall is altogether insufficient or too late for rice production. Total annual rainfall figures do not give information about reliability and intensity of rainfall. In seasons with less than 800 mm rainfall it is, however, practically impossible for many households to cultivate rice. Rainfall data from Ukiriguru (see Fig. 4.1 for location) show that this occurs in one out of three years for this part of Sukumaland. In such seasons households increase their sweet potato acreage to secure food production while households with access to vertisols and ox plough can still plant early maturing sorghum cultivars in March-April (Enserink et al., 1994).

Upper rice fields are the first to receive runoff water. In seasons with poor rainfall this is an important advantage. The fact that these fields are located at the top of the rice valley and are more sandy gives, however, higher losses of water from percolation and seepage. Fields in the valley bottom have the lowest percolation and seepage rates but have the disadvantage of too high water tables after heavy rainfall. Too high water tables are not beneficial to land preparation, germination, tillering, weeding, gap filling and transplanting. In Cambodia rainfed lowland rice farmers have given specific names to high, middle and low situated fields. Middle fields are preferred because they have less problems with both drought and floods (Lando and Mak, 1994). Fujisaka (1990) stressed, however, that field conditions in many rainfed lowland rice systems are interrelated and change each year because of differences in rainfall patterns. Also in Sukumaland it was observed that water conditions in upper, middle and lower rice fields depend on the intensity and spread of rainfall, which is different in each season.

Some farmers own adjacent fields, one above the other along the slope. These farmers can to a certain extent regulate the depth of water in their fields whenever the top fields are filled with water. Some farmers construct canals leading into their upper fields to increase the amount of runon water. Very few farmers can construct water storage reservoirs because other farmers will accuse them of monopolizing runoff water. Valley committees to regulate the distribution of water among rice fields are absent in Sukumaland. Several attempts have been undertaken to irrigate rice fields with surface water from rivers or Lake Victoria. One example is the Luchili irrigation scheme during the 1970s and 1980s, which used water from Lake Victoria at Luchili Bay near Sengerema town (Matsushita and Aino, 1984). Like all other past and recent attempts to irrigate rice fields in Sukumaland, this scheme failed from, among other things, inadequate cost-benefit calculations and insufficient government funds.

Other constraints

On the Maswa hardpan plain one out of ten rice heads is lost mainly from damage from birds and stemborers (Meertens and Ndege, 1993). This is a relatively small but is still a considerable reduction of yield. The damage from birds varies per season and per valley, and is more severe for early planted fields, early maturing cultivars without awns on the spikelets, and for households who fail to scare birds because of labour problems. In extreme cases households can lose more than half of their rice crop. Localized fields with severe infestations of stemborers sustain considerable losses. The *Tondogoso* and *Lugata* cultivars appear to be most susceptible to stemborer attacks. Rodents can also be a problem for rice in the field and rice stored in the house. The losses from diseases are very small in Sukumaland. Few fields, especially in virgin areas, are hit by rice blast (*Pyricularia oryzae*). The *Tondogoso* and *Lugata* cultivars appear to be the most susceptible to this disease (Meertens and Ndege, 1993).

Households living in villages not situated on vertisol or hardpan plains often think that their rice fields are not fertile enough. The natural fertility of more sandy soils in the valleys is indeed low and continuous cultivation of rice will lead here to declining yields relatively quickly. Very few of these households, however, apply mineral fertilizers or farmyard manure to their rice fields. High prices and poor availability restrict the use of mineral fertilizers. Transport of high amounts of farmyard manure from the kraal to the rice fields is difficult in the absence of oxcarts. Besides, half of the households in Sukumaland have no cattle (Meertens and Lupeja, 1996).

The very poor condition of most feeder roads in Sukumaland discourages many traders to supply agricultural inputs to the villages. In remote villages farmers are further forced to sell their crops at sharply reduced prices to those very few traders willing to come to their village. Beginning in 1991 subsidies on agricultural inputs were gradually removed in Tanzania. As a result, ratios between farmgate input prices and farmgate crop prices increased sharply, especially in the more remote villages. At present it is not profitable for most farmers to use agricultural inputs like herbicides, insecticides and mineral fertilizers. This leaves farmers with very few options to solve the above mentioned constraints.

Discussion and conclusions

This paper shows that a combination of ecological, economic, technological and population density factors stimulated the cultivation of rice in Sukumaland during the 1980s and 1990s. Farmers quickly adapted their farming systems according to changes in markets, available technologies and population densities. One important outcome was the intensification of land use in the valleys in the form of rainfed lowland rice cultivation as a way to secure the sustainability of the farming systems. Farmers' innovations, experimentations and agricultural knowledge even turned a semi-arid environment into a rice exporting area in spite of government negligence.

The relatively high rice yields (3-4 tonnes ha^{-1}) in seasons with favourable rainfall, despite the fact that farmers apply almost no farmyard manure or mineral fertilizers, indicate that most rice fields still have a satisfactory natural fertility. Rice cultivation in most valleys is still a fairly recent phenomenon and in one out of three years many rice fields are left to fallow because of insufficient rainfall. Negative nutrient balances as calculated by Stoorvogel and Smaling (1990) for nonfluvial flooded rice in Tanzania have not yet a major impact in Sukumaland. However, in the near future farmers, especially in areas dominated by sandy soils, will have to apply nutrients to their rice fields to reach yields of 3-4 tonnes ha^{-1} in seasons with good rainfall.

The detailed characterization of the rice cropping systems, description of management practices, and identification of constraints reveal the diversity of rice cultivation according to differences in ecological circumstances and household characteristics. Such detailed information is indispensable for a proper assessment of the current importance, performance and future possibilities of rice cultivation in Sukumaland. Research or extension programmes for rice in Sukumaland, and similar rice cropping systems in Tanzania and Africa, have to be based on adequate understanding of rainfed lowland rice cultivation in collaboration with farmers and have to acknowledge the diversity in households, rice valleys, rice fields and seasons.

Acknowledgements

The authors thank J. Brouwer, N. Röling and two anonymous referees for their valuable comments on earlier drafts of this paper. Thanks are also expressed to all rice farming households, extensionists and researchers in Sukumaland who exchanged their knowledge on rice cultivation with us. The assistance of Titia Hajonides in drawing the map is much appreciated.

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5 Blanket recommendation of a low dose of urea in the rainfed lowland rice fields of Sukumaland, Tanzania**

Abstract: On-farm soil fertility research in the rainfed lowland rice fields of Sukumaland in northwest Tanzania between 1990 and 1996 was a response to farmers' complaints about declining rice yields. Rice yields in Maswa district increased sharply after a low dose of nitrogen (30 kg N ha^{-1}) in the form of urea was broadcast in flooded rice fields at tillering. Similar activities were subsequently conducted in other parts of Sukumaland to evaluate this type of nitrogen application under varying circumstances. In 1995/96 also higher doses of nitrogen and a high dose of phosphorus were applied for comparison in Sengerema district. The average increase in rice yield from the application of 30 kg N ha^{-1} varied between 463 and 986 kg ha^{-1} during 1990-96. The crop yield response to urea was better when rice plants were at the maximum tillering stage, and when water depths were less than 15 cm at application, and when fields had higher sand contents. The application of 30 kg N ha^{-1} was more economical than 60 and 120 kg N ha^{-1}. No phosphorus deficiency was found in Sengerema district. The relatively small differences in response per field (environment) in all seasons did not justify a need for multiple extension messages. A single dose of 30 kg N ha^{-1} in the form of urea to rice at tillering is recommended for entire Sukumaland. Further research should concentrate on higher efficiency of nitrogen fertilization and on optimum rates of other major nutrients.

Keywords: Rice; Nitrogen fertilizer recommendation; Rainfed lowland; Urea; Tanzania

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** Submitted to *Field Crops Research*

Introduction

In the Mwanza and Shinyanga regions of northwest Tanzania (Fig. 5.1), also known as Sukumaland, rice has become a major food and cash crop in the past 25 years. This has been due to both population growth and the profitability of rice cultivation in comparison to other crops. Population growth reduced the average farmsize in many parts of Mwanza region. Rice is able to produce high amounts of calories on small pieces of land and this increased its popularity. In addition government control during the 1970s and 1980s caused a general decline in the producer price of cotton, the major cash crop in Sukumaland. The producer price for rice, however, remained favourable during this period, due to good, open markets for rice in the fast growing town of Mwanza and in neighbouring Kenya, Uganda, Rwanda and Burundi. As a result many farmers appear to have switched from cotton to rice by the end of the 1980s in the areas of Sukumaland with more than 800 mm average annual rainfall and favourable soils (hardpan and/or heavy clay soils) for rainfed lowland rice (Meertens et al., 1995).

In 1989 the FSR Project Lake Zone conducted a rapid rural appraisal covering twelve villages in the Maswa and Meatu districts of Shinyanga region. During this survey it was observed that the farming systems in the Sengerema division of Maswa district were dominated by rainfed lowland rice. Group discussions with farmers in villages from this part of Maswa district revealed that weeding was generally regarded as the main constraint in rice cultivation. Some farmers also mentioned that they experienced decreasing yields in their rice fields. Farmers further stated that they had been growing rice almost continuously on the same fields for the past 20-30 years with very little use of farmyard manure or mineral fertilizers (FSR Project Lake Zone, 1989). In the planning stage of the on-farm research, this led to the hypothesis that the decrease in yields was perhaps caused by a decrease in soil fertility. Observations of yellow rice plants during the rapid rural appraisal were also interpreted as indications of mineral deficiencies. Possible solutions to the weeding and soil fertility problems in rice were evaluated according to several criteria mentioned in Tripp and Woolley (1989) to optimize the chance of success. Simple cost-benefit calculations showed that the use of locally available herbicides could hardly be profitable. The ratio between fertilizer prices and rice farmgate prices was, however, more promising. It was decided to conduct a diagnostic on-farm trial in the Sengerema division to test if the use of farmyard manure and mineral fertilizers could significantly, and profitably, increase rice yields.

The cultivation of rainfed lowland rice in Sukumaland is based on trapping water from runoff and seepage in the lower parts of gently undulating slopes through the construction of small bunds around the rice fields (see Chapter 4). Rice fields are relatively small. In the Sengerema division of Maswa district rice field sizes range from 0.02 to 0.6 hectares with an average of 0.12 hectares (Meertens and Ndege, 1993). The soils in the valleys are mainly loamy hardpan soils or heavy clay soils with low infiltration rates. Such type of soils usually contain adequate quantities of potassium (Grist, 1975). The diagnostic trial was therefore aimed at identifying possible deficiencies in nitrogen and/or phosphorus. Treatments of the 1989/90 diagnostic on-farm trial were 30 kg N ha^{-1} at tillering in the form of urea, 20 kg P_2O_5 ha^{-1} at planting in the form of Triple Super Phosphate (TSP), the combination of 30 kg N ha^{-1} at tillering and 20 kg P_2O_5 ha^{-1} at planting, 5 tonnes ha^{-1} farmyard manure prior to landpreparation, and as a control the farmers' practice of no use whatsoever of organic or inorganic fertilizers. Farmyard manure was included because about half of the households own cattle in this part of Maswa district (Meertens et al., 1995). The results showed that the low dose of nitrogen increased rice yields far more (740 kg ha^{-1}) than the low dose of phosphorus (124 kg ha^{-1}), and the application of farmyard manure (192 kg ha^{-1}). The open kraal farmyard manure increased the number of weeds in the fields and this diminished the positive effect it had on soil fertility. The low dose nitrogen treatment was also much more economical than all other treatments (Meertens et al., 1991).

On the basis of the results from the diagnostic on-farm trial it was decided to continue only with the application of a low dose of nitrogen in the form of urea. An on-farm verification test was conducted during 1990/91 in the same two villages as the diagnostic on-farm trial. The application of urea proved to be profitable under a range of circumstances and this prompted the FSR Project Lake Zone to undertake a pre-extension campaign to convey this to a wider audience (Enserink et al., 1994). Pre-extension campaigns followed in the next two seasons, and an extension campaign was conducted by the Kilimo/FAO Plant Nutrition Programme during 1994/95 in Mwanza region. A nitrogen level on-farm trial was finally executed in Mwanza region during 1995/96 to investigate if other levels than 30 kg N/ha were more economical. One treatment contained also a high dose of phosphorus to detect any phosphorus deficiencies in this part of Sukumaland. This paper presents the results from all tests, trials and demonstrations, which followed the diagnostic on-farm trial, in an integrated way. It shows how a sequence of related on-farm activities and recognition of farmer financial limitations led to a recommendation on the application of a lower than often advised dose of nitrogen in rainfed lowland rice for Sukumaland in northwest Tanzania. It is analysed whether differences in soils, rainfall patterns, rice cultivars, planting methods and in the position of a field on the slope necessitate any change in the recommendation. An economic analysis in combination with farmers' assessment indicates if this technology can be adopted by rice farming households in Sukumaland.

There is much information available about the application of urea in rainfed lowland rice in Asia, but very little about the performance of urea in rainfed lowland rice in Africa. This paper can thus contribute to further development efforts and research on this topic in Africa, where the environment often differs significantly from that in Asia.

Materials and methods

Experimental area

The Mwanza and Shinyanga regions of Sukumaland border on Lake Victoria to the north, Kagera region to the west, Tabora region to the south and Ngorongoro Conservation Area and Serengeti National Park to the east (Fig. 5.1).

Average annual rainfall ranges between 700 mm and 1000 mm. The rainy season starts around mid-October and ends around mid-May. The pattern is bimodal, with peaks in November-December and March-April. Rainshowers are often very localized and unpredictable. Dry spells are common throughout the rainy season, but are most pronounced during January. Potential evapotranspiration rates of 4.5 mm day^{-1} occur

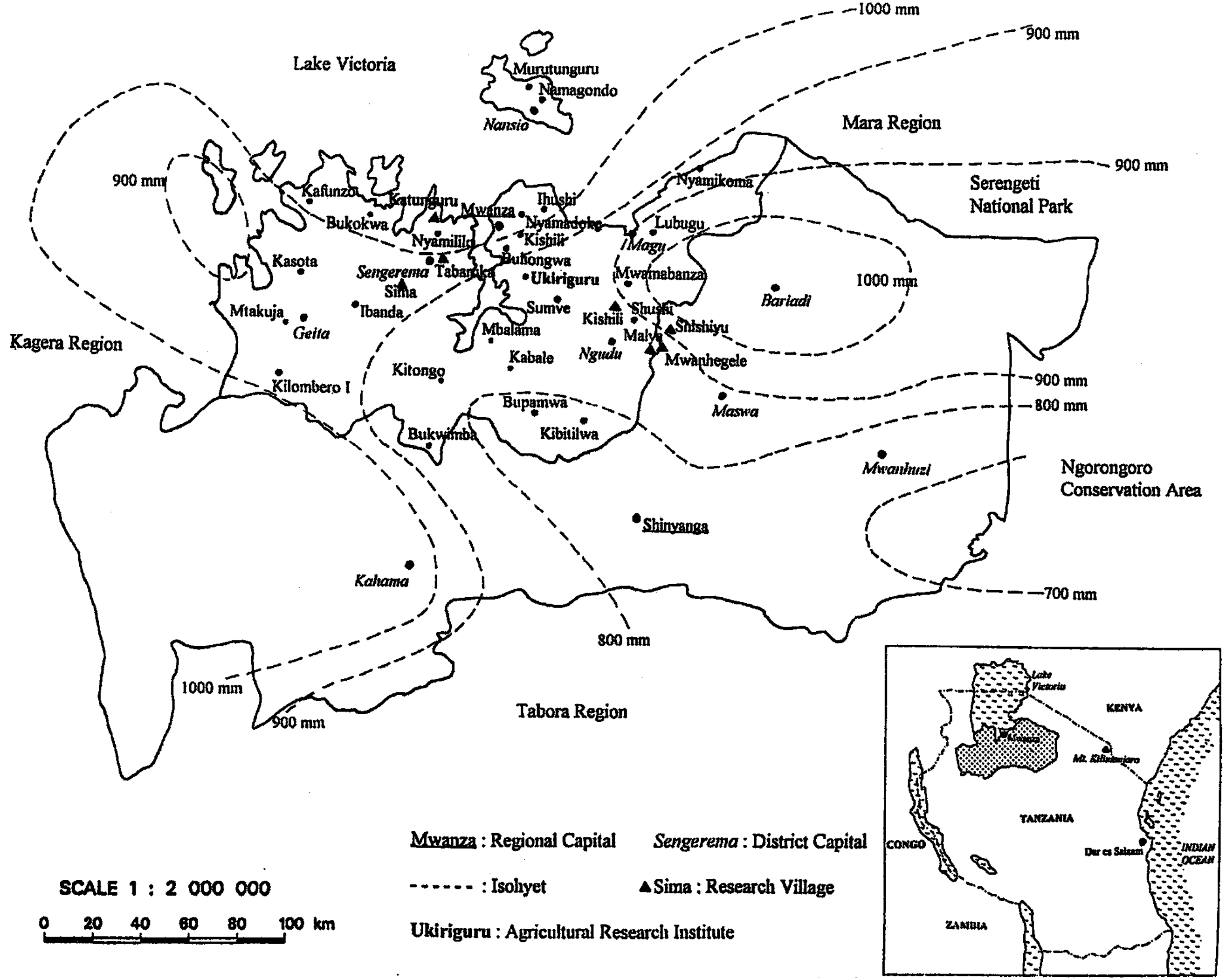


Fig. 5.1
Location of villages from 1990-1996 on-farm rice-fertilizer research in Sukumaland, Tanzania

during the rainy season (ICRA, 1991).

The landscape in Mwanza region is dominated by both broad and narrow valleys, separated by rocky hills that consist mainly of granitic and sometimes gneissic rocks. The landscape in Shinyanga region is characterized by vast fluvial and lacustrine plains, with sediments derived from the same type of rocks (Meertens et al., 1996). The cultivation of rice is more important in areas with gently undulating slopes, where the proportion of sandy clays with shallow hardpan soils (Solodic Planosols) within the catena is high (see Chapter 4). On the basis of criteria from Garrity et al. (1986) the rainfed lowland rice system in Sukumaland can be classified as drought-prone with a short rice growing season but relatively fertile soils.

The 1990/91 on-farm verification test was conducted in the same two villages as the diagnostic on-farm trial, namely Mwanhegele and Shishiyu, two villages in between Ngudu and Maswa towns (Fig. 5.1). The 1991/92 pre-extension campaign was conducted again in the same villages. The 1992/93 pre-extension campaign was conducted in Malya and Kishili villages, to the east and north of Ngudu respectively (Fig. 5.1). The extension campaign in Mwanza region during 1994/95 was done in 26 villages spread over the entire region (Fig. 5.1). The 1995/96 nitrogen level on-farm trial finally was conducted in Katunguru, Sima and Tabaruka, three villages near to Sengerema town in Mwanza region (Fig. 5.1).

Choice of treatments

The on-farm activities from 1990/91 to 1994/95 had two treatments; nitrogen application at the rate of 30 kg N ha^{-1} in the form of urea (46% N) and the farmers' practice, which is no application of organic or inorganic fertilizers and therefore equal to 0 kg N ha^{-1}. The 1995/96 nitrogen level on-farm trial had five treatments; the farmers' practice as control (0 kg N ha^{-1} and 0 kg P_2O_5 ha^{-1}), 30 kg N ha^{-1}, 60 kg N ha^{-1}, 60 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} and 120 kg N ha^{-1}. The nitrogen was again applied in the form of urea and the phosphorus in the form of TSP (46% P_2O_5).

In most situations, ammonium-containing (e.g. ammonium sulfate) or ammonium-producing (e.g. urea) fertilizers applied to flooded rice are similar in effectiveness. Urea has, however, the highest content of nitrogen and this reduces the cost of transport and eventually the price per kg nitrogen. That is why urea became the principal nitrogen fertilizer for rice in tropical Asia (De Datta, 1981). In Sukumaland, as well, urea turned out to be the cheapest source of nitrogen fertilizer (Meertens et al., 1991). To take account of the cash constraints in most households a low dose of 30 kg N ha^{-1} was chosen, which is somewhat less than the recommended 40 kg N ha^{-1} for Mwanza and Shinyanga regions (Samki and Harrop, 1984). For tall, leafy *indica* cultivars, such as the *Tondogoso*, *Lugata* and *Faya* cultivars in Maswa district (Meertens and Ndege, 1993), levels of 30-40 kg N ha^{-1} are appropriate. Higher levels will usually result in more lodging and excessive growth of straw (Grist, 1975; Ahn, 1993). The most important cultivars in Mwanza region are, however, short *indica* cultivars such as *Super*, *Rangi mbili* and *Sindano* (Lupeja and Meertens, 1996a). The 1995/96 nitrogen level on-farm trial included levels of 60 and 120 kg N ha^{-1} to see if levels higher than 30 kg N ha^{-1} were more appropriate for these cultivars with a lower susceptibility to lodging.

The application of the low dose of nitrogen (30 kg N ha^{-1}) in all on-farm activities was done in a single dose at tillering through broadcasting the urea on the flooded rice fields. The common way in Asia is to broadcast urea directly into the floodwater two to four weeks after transplanting rice (De Datta, 1987). Most cultivars in Sukumaland have a medium growth duration (145 days) and such cultivars use low doses of nitrogen fertilizer most efficiently during the maximum tillering as well as around the flowering stages (De Datta, 1981). The higher levels of nitrogen (60 and 120 kg N ha^{-1}) during 1995/96 were applied to flooded rice fields in split applications of equal amounts at tillering and booting. The phosphorus was applied at transplanting by broadcasting the TSP prior to puddling.

Sites description and experimental design

For the 1990/91 *verification test* (Meertens et al., 1992) we selected two rice valleys in each of Mwanhegele and Shishiyu villages. In each valley we selected six fields at as much as possible regular intervals down the slopes. In one valley farmers failed to plant rice on two fields due to drought. One field was added in another valley. Urea was finally applied to a total of 23 fields in a central strip of about 8 m x 15 m along the slope. Small, temporary ridges were constructed across the fields to avoid that urea would move with water from the strips. Three crop cuts of 3 m x 3 m were obtained at harvest from the fertilized and non-fertilized areas at each field. These were taken from upper, middle and lower parts of the fields to cover non-experimental variations along the slope. Crop cuts were paired to reduce the variation in variables other than fertilizer application between treatments. From each field a composite soil sample was taken shortly after the harvest. Table 5.1 presents the soil analysis data together with data from similar soils from other parts of Maswa district and shows that there was little difference. The rice soils in Maswa district have, according to criteria mentioned in Ngailo et al. (1994), a low amount of organic matter of moderate quality, a very low amount of total nitrogen, a low amount of available phosphorus and a medium amount of exchangeable potassium.

For the 1991/92 *pre-extension campaign* (Kajiru, 1993) 60 fields were selected in Mwanhegele and Shishiyu villages at various positions along the slopes. Urea was in the end applied to only 30 fields because farmers failed to plant rice in the other fields due to drought. Urea was applied to one half of each field along the slope and a small ridge was constructed to prevent movement of fertilizer from the fertilized area. Three crop cuts of 2 m x 2 m were taken at harvest from the fertilized and non-fertilized areas at each field. Crop cuts were taken from upper, middle and lower parts of the fields to cover non-experimental variations along the slope. Averages of the three cuts were calculated for each treatment. A total of 138 fields were selected for the 1992/93 *pre-extension campaign* (Kajiru, 1994) with varying positions along the slopes in Malya/Kishili villages. Urea could only be applied to 46 fields due to dry circumstances at the other fields. Experimental design and harvesting method were similar to the previous season.

The 1994/95 *extension campaign* in the entire Mwanza region (Lupeja and Meertens, 1996a) involved 160 rice farming households from 26 villages. Villages selected incorporated all possible combinations of rainfall patterns and dominant soil types present in Mwanza region. Extension workers were instructed to select equal numbers of rich, average and poor households. Due to the high number of households we also obtained a fair number of rice fields in different parts of the slopes. An extension leaflet in Kiswahili for extension workers and farmers on the efficient use of urea in rice prepared by the FSR Project Lake Zone was used for demonstrating the application of urea in rice to farmers in Mwanza region. Urea was applied to 157 fields; three households failed to plant rice due to drought. The urea was applied in a central strip of about 10 m x 15 m across each field along the slope. As in previous experiments, small, temporary ridges were constructed to prevent movement of the fertilizer from the fertilized area. The fertilized strip of about 150 m^2 was harvested and compared with two unfertilized areas of about 75 m^2 to the left and right of the fertilized strip. This was done to reduce the influence of variables other than fertilizer application. After urea application we failed to harvest one field due to the death of the farmer and another field due to drought, leaving us with results from 155 fields.

Table 5.1
Analytical data from composite soil samples in rice valleys of Maswa district

	Samples from 1990/91 verification test[a] Average	Range	Samples from 1991 Soil Survey[b] Average	Range
Sand %	59.9	39 - 84	-	-
Silt %	10.9	5 - 15	-	-
Clay %	29.2	11 - 49	-	-
pH-H_2O	6.8	5.6 - 8.1	7.1	5.6 - 8.4
Org. C g kg^{-1}	12.4	3.2 - 19.5	10.0	3.0 - 19.0
Total N g kg^{-1}	0.9	0.4 - 2.1	0.7	0.3 - 1.4
C/N	14	5 - 25	14	10 - 18
P-Bray mg kg^{-1}	2.9 (17 sites)	0.7 - 12.0	6.3 (4 sites)	2.0 - 10.0
P-Olsen mg kg^{-1}	3.0 (6 sites)	1.0 - 5.0	3.1 (7 sites)	1.0 - 5.0
CEC meq $100g^{-1}$	18.5	5.4 - 32.0	16.9	1.3 - 51.4
Na meq $100g^{-1}$	0.76	0.23 - 1.65	0.64	0.12 - 1.51
K meq $100g^{-1}$	0.25	0.04 - 0.87	0.37	0.11 - 0.83
Ca meq $100g^{-1}$	15.85	1.6 - 32.48	6.62	0.5 - 16.5
Mg meq $100g^{-1}$	2.22	0.48 - 4.12	1.82	0.20 - 4.60

a Taken at the end of the season from 23 sites to a depth of 0-20 cm (Meertens et al., 1992)

b Taken at the end of the season from topsoils at 11 sites within mapping unit L2 in different parts of Maswa district (Ngailo et al., 1994)

In the 1995/96 *nitrogen level on-farm trial* (Lupeja and Meertens, 1996b) we selected a total of 45 fields, 15 fields each in the Katunguru, Sima and Tabaruka villages. These fields were located in the upper, middle and lower parts of several slopes. In most cases we were able to divide the rice field in five subplots of about 50 m^2 (5 m x 10 m). The five treatments were randomized at each field. Small, temporary ridges were constructed between treatments to avoid movement of fertilizers from one plot to another. Yields were obtained from the harvest of the whole subplot. Heavy rains came very late in Sima and Tabaruka and stopped too early. Due to this farmers failed to plant rice in seven fields and in another seven fields we failed to apply all required urea. One field was destroyed by goats. In the remaining 15 fields of these villages results were too much affected by the delays in urea application. We thus had valid results only from the 15 fields in Katunguru.

Non-experimental variables

We as researchers made sure that urea was only applied to weeded, moist rice fields. Apart from that all other management practices were left to the rice farming households. This enabled the evaluation of the performance of urea under different, realistic farmers' circumstances. Variations in landpreparation, planting dates and methods, weeding practices, cultivars, water availability etc. were recorded. Data were also collected on the circumstances at urea application (water depth, number of tillers), plant population at harvest, position of the field on the slope, type of soil, rainfall and grain yield after sufficient drying. These field data were combined with farmgate prices for rice, labour and fertilizers and with information from farmers' opinions and observations. All this information was used to evaluate the performance of the low dose of nitrogen in rainfed lowland rice under different agroecological and socio-economic conditions in Sukumaland.

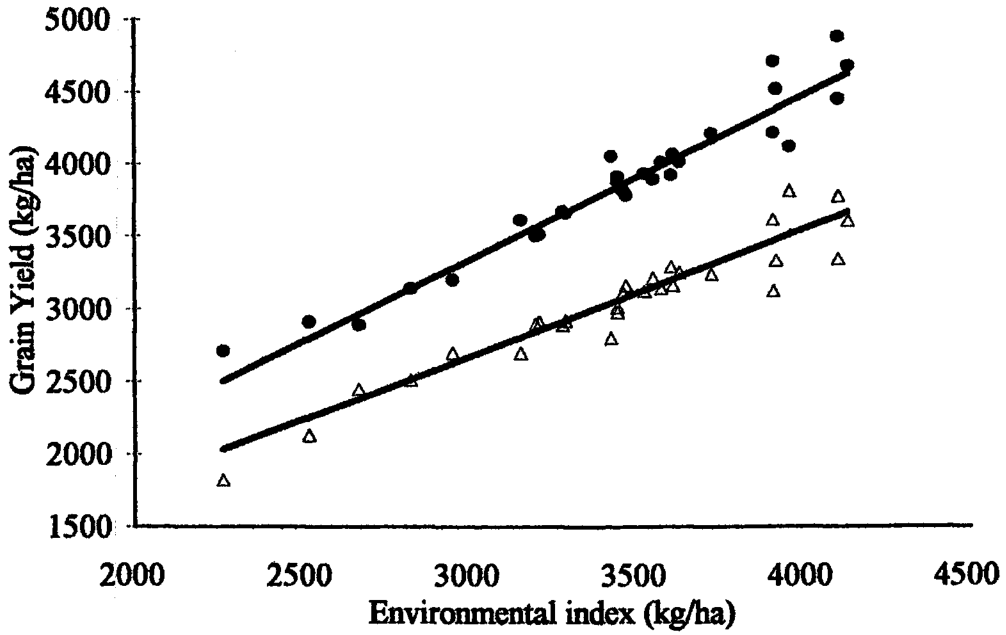
Table 5.2
Rice yield response to urea application (30 kg N ha^{-1}) in relation to soil texture, number of tillers at application and water depth at application in the 1990/91 verification test in Maswa district

Variable	Level[a]	Control yield (kg ha^{-1})	Urea yield (kg ha^{-1})	Increase (kg ha^{-1})	Increase %
Sand	39-55% (n=9)	4118	4714	596	14
	56-70% (n=9)	4444	5123	679	15
	71-85% (n=5)	3237	3950	713	22
Tillers	1-3 (n=30)	3694	4352	658	18
	3-5 (n=30)	4498	5111	613	14
	5-9 (n=6)	4280	4706	426	10
Water depth	0-5 cm (n=20)	3646	4445	799	22
	5-15 cm (n=29)	4338	5043	705	16
	15-30 cm (n=14)	4204	4645	441	10

a Number of observations ( ) for number of tillers and water depth based on sample plot data and for percentage of sand based on composite soil samples for each field

Source: Meertens et al. (1992)

Fig. 5.2
Regressions of farmers' practice (0N) and urea application (30N) on environmental index (e) for the 1991/92 rice pre-extension campaign in Maswa district (30 fields)



Δ 0N
— Y (0N) = -51 + 0.896 x e (kg/ha)

● 30N
— Y (30N) = 51 + 1.104 x e (kg/ha)

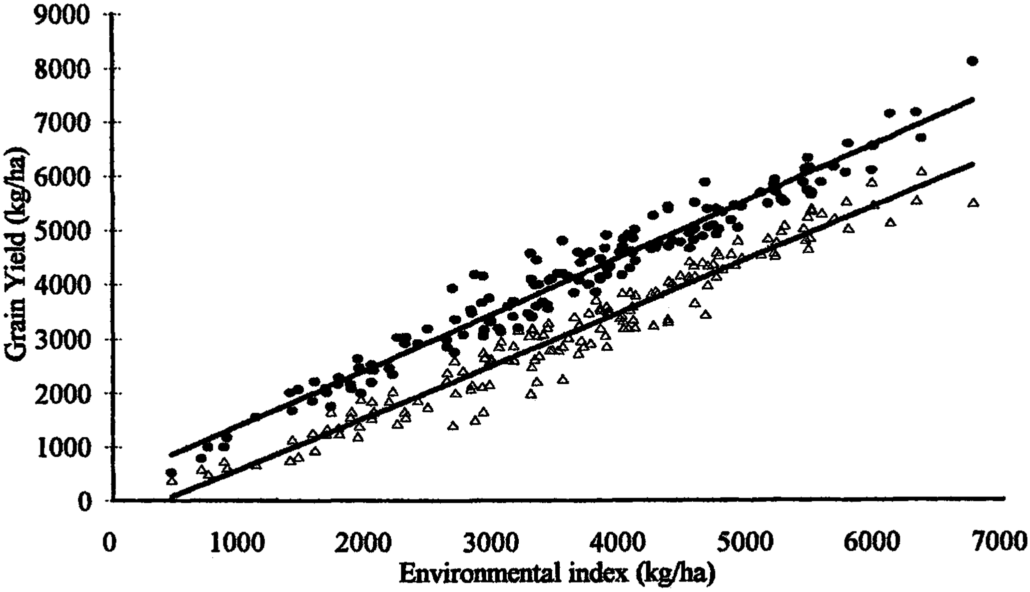
Results

Verification test

In the 1990/91 urea verification test the three crop cuts in the upper, middle and lower parts of the fields served as replicates. A combined analysis of variance over all fields was possible due to homogeneous error variances at the fields (Neeley et al., 1991). The coefficient of variation of this combined analysis of variance was only 10.7%. Effects of fields, replicates and urea application on rice grain yields were significant at the 1%-level of probability. The field x treatment interaction was, however, not significant at the 10%-level of probability. The latter means that the selected fields belonged to the same recommendation domain with regard to the application of a low dose of nitrogen. Table 5.2 shows that there were differences in the effect of urea on rice yield according to variations in soil type, water depth at application and tiller stage at application. Correlation coefficients between increase in rice yield due to urea application and soil type, water depth at application and tiller stage at application were, however, not significant at the 5% level of probability.

Over all 23 fields the application of urea (30 kg N ha^{-1}) increased the average control grain yield of 4067 kg ha^{-1} with 641 kg, to 4708 kg ha^{-1}.

Fig. 5.3
Regressions of farmers' practice (control=0N) and urea application (30N) on environmental index (e) for the 1994/95 rice extension campaign in Mwanza region (155 fields).



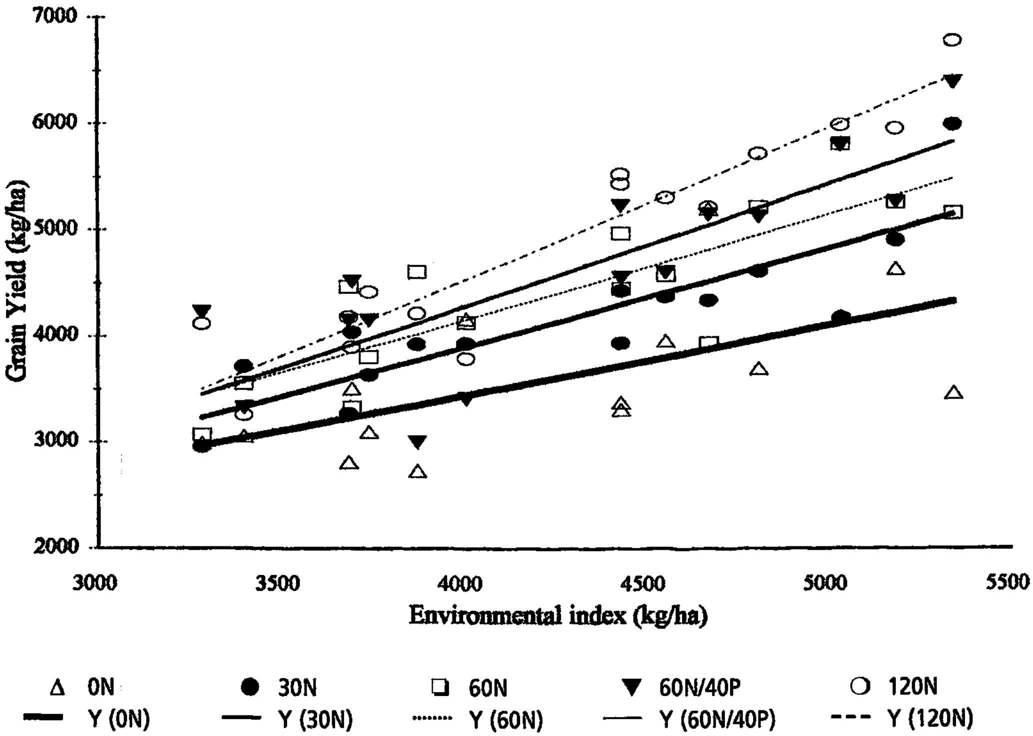
Δ 0N
— Y (0N) = -376 + 0.968 x e (kg/ha)

● 30N
— Y (30N) = 376 + 1.032 x e (kg/ha)

Pre-extension campaigns

The crop cuts in the 1991/92 and 1992/93 pre-extension campaigns were not paired and could thus not serve as replicates. With only one replicate per field, a combined analysis of variance over fields cannot be carried out to provide information about the interaction between treatment and field. In this situation adaptability analysis (Hildebrand and Russell, 1996) is an alternative way to see if treatments vary over fields. In adaptability analysis treatments are compared to the environmental index, which is the mean yield of all treatments at each field. The environment is the product of the entire set of biophysical and socioeconomic factors. In our case the environment varied according to differences in management (landpreparation, type of planting, weeding etc.), soils, cultivars, circumstances at urea application, rainfall and position of the field on the slope. Figure 5.2 shows the regression lines of the farmers' practice (0N) and urea application (30N) on the environmental index for the 1991/92 pre-extension campaign. In the combined analysis of variance on rice grain yields the difference in regression of the farmers' practice and urea application on the environmental index (Mutsaers et al., 1997) is not significant at the 5% level of probability, while urea application and fields are significant at the 1% level of probability. This points to no clear interaction between treatment and fields despite

Fig. 5.4
Regression of 1995/96 N-level trial treatments on environmental index (e) in Katunguru village (15 fields)



Y (0N) = 791 + 0.660 x e (kg ha^{-1})
Y (30N) = 186 + 0.927 x e (kg ha^{-1})
Y (60N) = 205 + 0.987 x e (kg ha^{-1})
Y (60N + 40P) = -323 + 1.150 x e (kg ha^{-1})
Y (120N) = -1186 + 1.427 x e (kg ha^{-1})

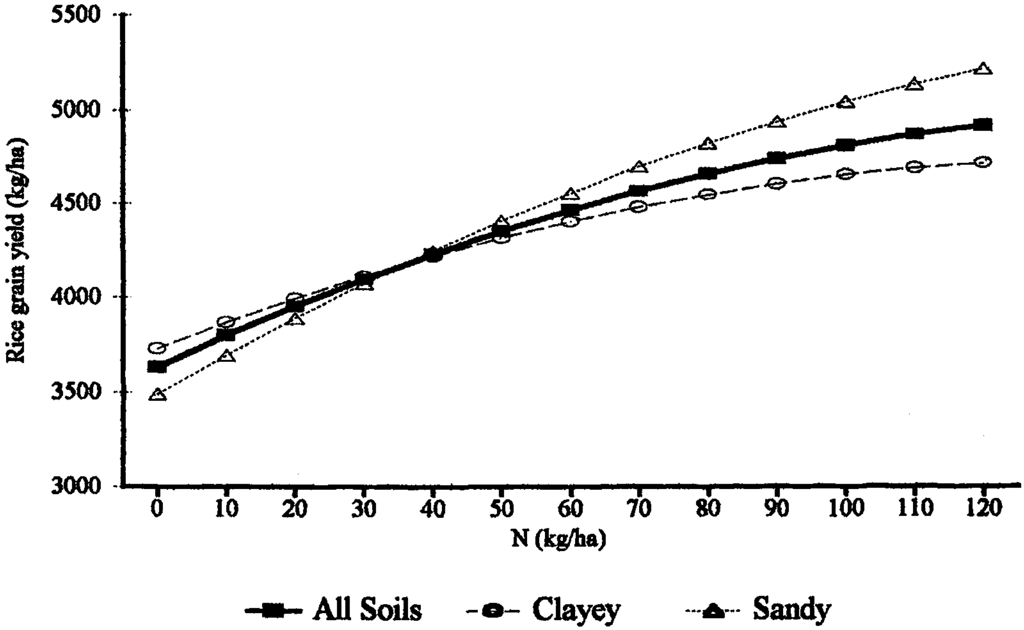
that Kajiru et al. (1998) found significant interactions between urea application and cultivar ($P<0.05$), position of field on the slope ($P<0.01$) and water depth at urea application ($P<0.01$) for the 1991/92 pre-extension campaign.

The application of 30 kg N ha^{-1} increased the average control grain yield of 3057 kg ha^{-1} with 824 kg, to 3881 kg ha^{-1} during 1991/92. In 1992/93 the average control grain yield of 3088 kg ha^{-1} was increased with 463 kg, to 3551 kg ha^{-1}. Calculations from linear regression analysis showed that each additional centimetre water depth at urea application reduced the beneficial effect on rice yield by an estimated 67 kg ha^{-1} during 1991/92 (Kajiru et al., 1998) and by 53 kg ha^{-1} during 1992/93 (Kajiru, 1994).

Extension campaign in Mwanza region

The 1994/95 extension campaign in Mwanza region of urea (30 kg N ha^{-1}) application in rice involved only one replicate per field. Again an adaptability analysis was used to detect any interaction between treatment and field. Figure 5.3 shows its results.

Fig. 5.5
Response curves to nitrogen according to soil type for Katunguru village in the 1995/96 N-level trial in Mwanza region



Y (all soils) = 3633 + 0.017 x N - 0.000053 x N^2 (kg ha^{-1} per kg N; r^2 = 0.32)
Y (clayey) = 3730 + 0.0172 x N - 0.0000503 x N^2 (kg ha^{-1} per kg N; r^2 = 0.29)
Y (sandy) = 3488 + 0.0164 x N - 0.0000571 x N^2 (kg ha^{-1} per kg N; r^2 = 0.42)

The difference in regression of the farmers' practice (0N) and urea application (30N) on the environmental index is not significant at the 5% level of probability but urea application and fields are significant at the 1% level of probability.

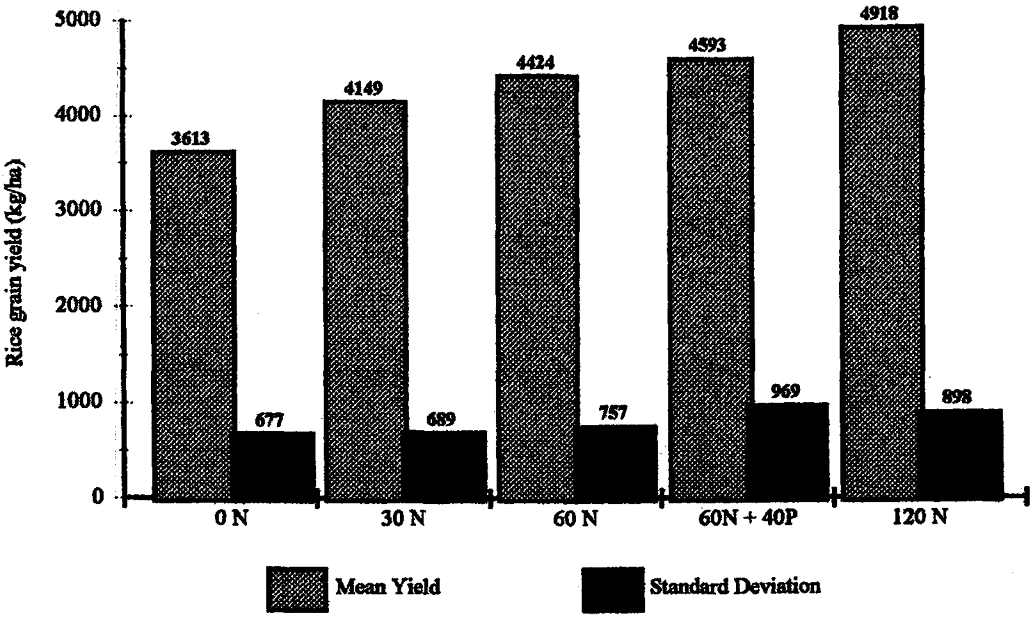
The application of urea increased the average control grain yield of 3127 kg ha^{-1} with 986 kg, to 4113 kg ha^{-1}.

Nitrogen level trial

The 1995/96 nitrogen level trial in the Sengerema district of Mwanza region involved also only one replicate per field. The results of the adaptability analysis for Katunguru village are presented in Figure 5.4. The differences in regression of the treatments on the environmental index are not significant at the 10% level of probability while treatments and fields are significant at the 1% level of probability.

In Figure 5.5 response curves to nitrogen application are shown separately for clayey soils, sandy soils and all soil types together for Katunguru village. The mean yields with standard deviations for all treatments are presented in Figure 5.6. All fertilizer applications are significantly ($P<0.05$) different from the control. Treatment

Fig. 5.6
Mean treatment yields with standard deviations for the 1995/96 N-level trial in Katunguru village, Mwanza region



$N_{60}P_{40}$ is significantly better than N_{30}, and N_{120} significantly better than N_{30} and N_{60} ($P<0.05$).

Discussion

Discussion of agronomic data

On the on-farm control plots annual average rice yields varied between 3 and 4 tonnes grain ha^{-1} from 1990 to 1996 (Table 5.3). A rapid rural appraisal in Mwanza region during 1994 (Meertens and Lupeja, 1996) revealed that the average rice yield from farmers' fields over all kind of seasons is near 2300 kg ha^{-1}. A survey in Maswa district (Meertens and Ndege, 1993) indicated an average of about 2800 kg ha^{-1} for farmers' rice fields in 1990/91. The higher control plot yields in Table 5.3 for 1995/96 in Mwanza can be explained by better water availability due to the selection of a valley with a large water catchment area, and for 1990/91 in Maswa and 1994/95 in Mwanza by better water availability due to good rainfall. Generally the rice yields from farmers' fields in Sukumaland are in the upper range of reported yields from farmers' rainfed lowland rice fields in Asia (De Datta et al., 1988; Fujisaka, 1990).Unlike Asia Sukumaland rice cultivation is a fairly recent phenomenon and furthermore in one out of three years many rice fields are left to fallow because of insufficient rainfall (see Chapter 4).

Table 5.3
Rice yields (kg ha^{-1}) with and without application of 30 kg N ha^{-1} in Sukumaland

Season	n[a]	Area/Soils	Rainfall (mm)[b]	Yield 0 N	Yield 30 N	Yield Increase (kg ha^{-1})	%
1990/91	23	Maswa/Hardpan	1033	4067	4708	641	16
1991/92	30	Maswa/Hardpan	814	3057	3881	824	27
1992/93	46	Kwimba/Hardpan	800	3088	3551	463	15
1994/95	155	Mwanza/Mixed	1137	3127	4113	986	32
1995/96	15	Sengerema/Vertisol	817	3613	4149	536	15

a n = total number of observations
b Rainfall data from Maswa town (1990-92), Ukiriguru (1992/93), average from Mwanza region stations (1994/95) and Sengerema town (1995/96)

The increase in yield from application of a low dose of nitrogen (30 kg N ha^{-1}) varied between years from 463 to 986 kg ha^{-1}. The variation in response to urea application among the seasons is due to variation in rainfall, soil type and circumstances at urea application. Performance was less optimal in 1990/91 because urea was for research reasons also applied to rice fields in the late tillering stages and/or with high water depths. The low dose of nitrogen is used most efficiently by the Sukumaland rice cultivars at the maximum tillering stage, which is the time when rice plants have 1-3 tillers. High water depths at application increase the loss of nitrogen through ammonium volatilization (De Datta, 1987). Urea performed better in 1991/92 and 1994/95 because in these extension efforts farmers were advised to apply urea in rice fields with low water depths and low number of tillers. There were furthermore no serious water constraints. In 1992/93 the effect of urea application was less due to drought and in 1995/96 due to the higher fertility of the selected vertisol valley in Katunguru.

The average productivity index (kg increase rice yield kg^{-1} applied nutrients) over all seasons is 23. Similar productivity indices of 22-27 were obtained with low doses of urea (29-30 kg N ha^{-1}) in rainfed lowland rice in the Philippines (De Datta et al., 1988). A much lower productivity index of 12.8 was obtained with an NPK treatment (60 kg N + 13 kg P_2O_5 + 25 kg K_2O ha^{-1}) in rainfed lowland rice in Thailand (Khunthasuvon et al., 1998). The best NPK treatment (41 kg N + 19 kg P_2O_5 + 10 kg K_2O ha^{-1}) of the FAO Fertilizer Programme (1961-1986) applied to rice fields in Tanzania had a productivity index of 17.5 (FAO, 1989 p. 70). Research in Asia has shown that incorporation of urea before transplanting and the use of modified urea products (sulfurcoated urea, urea supergranules) increase the efficiency of nitrogen application in lowland rice (De Datta, 1987). However, deep placement of urea supergranules has very limited adoption in Asia because of high labour requirements with hand placement and availability problems (Mohanty et al., 1999).

Apart from circumstances at urea application, soils and rainfall there were a number of other variables (e.g. valley, cultivar, weeding practice) and several interactions between variables which had also an effect on the performance of the low dose of nitrogen (30 kg N ha^{-1}) in the selected rice fields. The differences in response per field (environment) were, however, not significant in all seasons. Cultivars, soils, position of field on the slope, planting method, water depth at urea application and rainfall are all embedded in environment and each analysis for a single variable is less meaningfull due to correlations with, and importance of, other variables. Choice of cultivar is for example correlated with position of field on the slope (see Chapter 4). Figures 5.2, 5.3 and 5.4 show that increase in yield is higher at fields with a higher environmental index. A higher environmental index can reflect not only good water availability and favourable soils but also good management practices (timely and proper landpreparation, planting, weeding and harvesting). However, the response to the low dose of nitrogen is by and large constant throughout Sukumaland for all kind of years. The effect of urea application is strong enough to overcome the combined influence from all variables on its performance.

The variation in response to applications of nitrogen higher than 30 kg N ha^{-1} and to application of phosphorus (40 kg P_2O_5 ha^{-1}) between fields (environment) was also not significant. Figure 5.4 shows, however, that especially applications of high nutrient doses ($N_{60}P_{40}$ and N_{120}) perform relatively better in fields with otherwise optimum circumstances. Almost all fields in Katunguru were planted with the *Super* cultivar. Response curves in Figure 5.5 show that this cultivar had no lodging problems when high doses of nitrogen were applied in 1995/96. Fields with clay soils (*mbuga*) respond less vigorously to the application of nitrogen due to higher natural fertility (Fig. 5.5). No significant difference between N_{60} and $N_{60}P_{40}$ tends to confirm that there was no important phosphorus deficiency in this valley of Katunguru village.

Economic analysis and farmers assessment

During the 1970s and 1980s mineral fertilizers were subsidized by the Tanzanian government to encourage their use by farmers, especially the maize growing households in the south, in order to become self-sufficient in food. By 1988/89 mineral fertilizers had an implicit subsidy of up to 80 percent (World Bank, 1994). Reform programmes from IMF/World Bank forced the government to phase out the subsidy gradually from 70 percent in 1990/91 to zero in 1994/95. Devaluation of the Tanzanian shilling increased prices for inputs even further.

The average value cost ratio (VCR) for the low dose of nitrogen (30 kg N ha^{-1}) in rice was 13.8 in 1990/91, 11.7 in 1991/92, 5.8 in 1992/93, 4.8 in 1994/95 and 2.3 in 1995/96. The removal of subsidy on urea has clearly reduced the profitability of applying 30 kg N ha^{-1} in rice enormously. In 1995/96 the increase in rice yield had to be 457 kg ha^{-1} to reach a VCR of 2, which is considered to be the minimum level acceptable to farmers (FAO, 1989). Table 5.3 shows that attaining such a yield increase through applying 30 kg N ha^{-1} will be very difficult in seasons with adverse rainfall.

The results from the 1995/96 nitrogen level on-farm trial in Katunguru were subjected to a partial budget and marginal analysis (Lupeja and Meertens, 1996b). Only the N_{30} treatment had a marginal rate of return higher than 100% and this is necessary to make a technology adoptable under small farmers' circumstances (CIMMYT, 1988). The marginal rate of return for the N_{60} treatment in comparison to the N_{30} treatment was 15%, and for the N_{120} treatment in comparison to the N_{60} treatment only 8%. The $N_{60}P_{40}$ treatment had a lower net benefit than all other fertilizer application treatments. So these treatments are unattractive to farmers.

In all seasons farmers were impressed by the increase in rice yield from the application of 30 kg N ha^{-1} in the form of urea. Broadcasting of the fertilizer in flooded rice fields is easy and can be done in less than a day for an entire hectare. The interactions of this technology with farmers' cultural practices is that weeding has to be done prior to application. Secondly, high water depths at application are to be avoided. The unreliable rainfall pattern in Sukumaland prevents farmers, however, from drastic drainage actions prior to urea application. To farmers, the advantage of applying urea to flooded rice fields is that the risk of losing the invested cash due to drought, even in seasons with unfavourable rainfall, becomes less. Moreover, at the recommended time of application farmers are in a position to fairly accurately predict success or failure of a particular rice field (Enserink et al., 1994). Unfortunately, farmers complained that the high farmgate price of urea and the fact that urea is not available in many villages prevents them from purchasing it. This is discussed further in Chapter 6.

Conclusions

The rice-fertilizer on-farm activities in Sukumaland between 1990 and 1996 show that a low dose of nitrogen (30 kg N ha^{-1}) in the form of urea at maximum tillering to flooded rice fields increases grain yield significantly. Response to application of 30 kg N ha^{-1} is stable throughout Sukumaland, indicating that nitrogen deficiency is common in these rainfed lowland rice fields. No significant differences in response to urea application exist between fields due to the low level of applied nitrogen. Adaptability analysis underlines that there is no need for multiple extension messages.

The average productivity index of 23 over all seasons for broadcasting 30 kg N ha^{-1} at tillering shows that nitrogen was used in a fairly efficient way. The deteriorating ratio between rice farmgate price and urea requires, however, higher rates of efficiency. On-farm research in the rainfed lowland rice fields of Sukumaland is needed to evaluate alternative methods of urea application both agronomically and economically.

On-farm research in one village during 1995/96 showed that a dose of 30 kg N ha^{-1} was more efficient and economical than doses of 60 kg N ha^{-1} and 120 kg N ha^{-1}. No significant response was found to the application of 40 kg P_2O_5 ha^{-1} indicating that phosphorus is not deficient in the rice fields of that village. Further research in more villages and over more seasons is needed to confirm these results. Nutrient balance calculations are further needed to evaluate the long-term sustainability of applying a low dose of nitrogen in Sukumaland rice fields.

Acknowledgements

The results presented in this paper were obtained in close cooperation with many farming households, village extension officers, district/regional agricultural officers, in particular P.M. Lupeja, and researchers from Ukiriguru Agricultural Research Institute. All are thanked and we hope that this paper reflects in a good way our joint efforts in Mwanza and Shinyanga regions. The assistance of Titia Hajonides in drawing the map is much appreciated.

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6 Non-Adoption of a Rice Fertilizer Technology based on a Farming Systems Research-Extension Methodology in Sukumaland, Tanzania: A Search for Reasons*

Abstract: A rice-urea technology, involving the application of a low dose of nitrogen (30 kg N ha^{-1}) to rice plants at tillering, was developed between 1990 and 1996 according to a FSRE methodology in Sukumaland, northwestern Tanzania. Farmers, however, did not adopt this technology. Analysis showed that the main factors behind this non-adoption were availability problems of urea in the villages and a decreasing profitability of the rice-urea technology due to IMF/World Bank instigated reform measures. Non-adoption was also due to low participation of farmers during priority setting of on-farm activities; poor involvement of the extension service; confusing research messages related to rice soil fertility management; and the high degree of uncertainty in the Sukumaland farming systems. We conclude that the FSRE methodology needs strong and institutionalized links with the extension service, commodity research and policy makers for effective adoption of agricultural technologies. A better coordination of activities between donors and governments is an essential precondition to make such links work.

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* Submitted to *Journal of Extension Systems*
The Journal requested to shorten the final version

Introduction

Farming Systems Research-Extension (FSRE) related activities started in Tanzania in the mid-seventies. In 1982 the Tanzania National Agricultural Policy stated that agricultural research should be more problem-oriented and a general adoption of the farming systems approach was proposed. In 1985 FSRE practitioners in Tanzania agreed on the CIMMYT approach to FSRE (Enserink and Sungusia, 1987). By 1988 the agricultural research system was reorganized into six agroecological zones. Both agricultural research and FSRE were now organized by zone and this facilitated the coordination between commodity and adaptive research. In 1988 the FSR Project Lake Zone, supported financially and technically by the Tanzanian and Netherlands governments, was one of the first FSRE projects in Tanzania with a zonal orientation (Enserink et al., 1994a).

One of the two target areas in which the FSR Project Lake Zone concentrated its activities were the Maswa and Meatu districts to the southeast of Lake Victoria in northwestern Tanzania. Briefly, the Maswa and Meatu districts of Shinyanga region have population densities ranging between 25 and 75 people km^{-2}. Average annual rainfall varies from 950 mm in the northwest of Maswa district to about 700 mm in the southeast of Meatu district. Generally altitude is 1200-1300 m above sea level (FSR Project Lake Zone, 1989). The landscape is characterized by broad valleys separated by rocky hills that consist mainly of granitic and sometimes gneissic rocks. There are also several vast alluvial (lacustrine) plains,derived from the same type of rocks. Typical soil catenas have developed in the granite parent material. Most valleys are gently undulating to almost flat, with alkaline, sandy clay hardpan soils as dominant soil types. Dominant soil types in the vast plains are calcareous, friable clay loams (Meertens et al., 1996).

After a study of secondary data sources an informal survey (rapid rural appraisal) covering ten villages was conducted in the Maswa and Meatu districts halfway 1989. Key problems and constraints for farming households were identified during group discussions with farmers. Topics which could be addressed by the FSR project were selected and described in more detail. After evaluation of possible solutions with district authorities and commodity researchers the project team selected a number of diagnostic on-farm experimental activities for the 1989/90 season. One of these activities focused on soil fertility problems in rice cultivation. To test the hypothesis of low soil fertility the FSR project conducted a diagnostic on-farm rice fertility trial in northwestern Maswa district. The rice production system was regarded as most suitable for efficient fertilizer use. In comparison to sorghum, cotton and maize, it has a better control of weeds and a much higher return to family labour (Enserink et al., 1994a). The application of a low dose of nitrogen (30 kg N ha^{-1}) in the form of urea at tillering appeared to be the most promising treatment both agronomically and economically in the 1989/90 diagnostic on-farm rice activity. The profitable use of urea in rice was confirmed in an on-farm verification test during 1990/91 and this led to the planning of a pre-extension campaign (Enserink et al., 1994a). The application of the low dose of nitrogen remained profitable during the 1991/92 pre-extension campaign in Maswa district and during the 1992/93 pre-extension campaign in neighbouring Kwimba district of Mwanza region. However, the performance of urea in 1992/93 was less, due to drought. In 1994 the FSR project prepared an extension leaflet in Kiswahili for extension workers and farmers on the efficient use of urea in rice. This extension leaflet was used in 1994/95 by the Kilimo[1]/FAO Plant Nutrition Programme in Mwanza region for demonstrating the application of urea in rice to farmers. The very good rainfall in 1994/95 and the use of the extension leaflet made the application of urea profitable in the majority of rice fields (see Chapter 5).

The good performance of applying a low dose of nitrogen (30 kg N ha^{-1}) at tillering in rice during on-farm activities between 1990 and 1996 did not, however, lead to adoption of this technology by farmers. No specific adoption surveys among farming households were necessary to establish this, due to obvious very low adoption rates. The FSRE methodology was, however, introduced expressly to improve the adoption rate of agricultural innovations by farm households. This paper looks for the reasons behind the non-adoption by farmers in Mwanza and Shinyanga regions, also known as Sukumaland, of a profitable rice fertilizer technology emanating from an FSRE methodology. The non-adoption by farmers is investigated by looking at the type of technology, the compatibility with the farming systems and the institutional setting. First we give an overview of factors which can affect the adoption of agricultural innovations. After a more detailed description of the rice-urea technology FSRE process in Sukumaland we look at the factors which hampered the adoption of this technology. The discussion presents some suggestions for improvements to adoption of technologies generated by FSRE programmes, and reveals some limitations of the FSRE concept with regard to adoption of agricultural innovations.

Factors affecting adoption of agricultural innovations

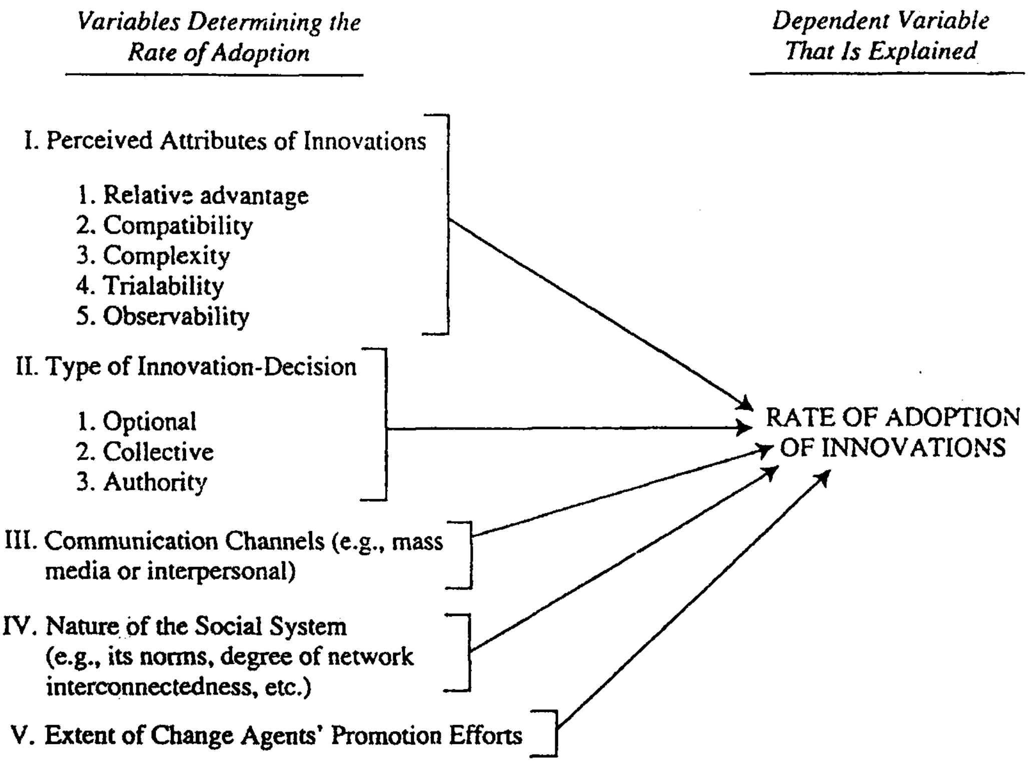
Research on the adoption or diffusion of innovations was mainly started by sociologists and anthropologists, especially in the United States of America. In the beginning rural sociologists dominated this type of research but later it was also taken up by educationalists, medical sociologists, economists, communication researchers and geographers. Each of these disciplines conducted diffusion research by emphasizing aspects of their field (Rogers, 1995).

This paper concerns the adoption of an agricultural innovation (broadcasting urea fertilizer in rainfed lowland rice) in Tanzania. This means we are particularly interested in factors which influence the adoption of agricultural innovations in the context of a developing country. In this section of our paper we therefore present the results of diffusion research by rural sociologists in the United States of America, by economists dealing with adoption of Green Revolution technologies in developing countries, by FSRE practitioners, and by researchers concentrating on adoption of fertilizer use by African farmers.

Early diffusion research in the United States of America

During the 1950s and 1960s agricultural research stations in the United States of America developed a very high number of farm innovations. These innovations led to a rapid increase in agricultural productivity, due to high adoption rates by farmers. Diffusion research had exploded in the 1950s and laid the foundation of an effective diffusion of innovations (Rogers, 1995). It was found that innovations were not adopted at the same time by all individuals. Research showed that the cumulative number of adopters follows an s-shaped curve when plotted over time. Individuals or other units of adoption were characterized by Rogers (1995) as innovators, early

Figure 6.1
Variables determining the rate of adoption of innovations



Source: Rogers, 1995

adopters, early majority, late majority and laggards in relation to the time of adoption. Diffusion research concentrated on the characteristics of these adopter categories. It appeared that education, social status, farm size, social participation, farm income, extension officer contact, mass media exposure and opinion leadership were positively correlated with the adoption of agricultural innovations by farm households (Rogers, 1995).

Initially relatively little effort was devoted by the diffusion research to the attributes of innovations which might influence their rate of adoption in a community or organization. Rogers (1995) described five attributes of innovations; relative advantage, compatibility, complexity, trialability and observability. Relative advantage is the degree to which an innovation is regarded as being better than the current practice. Such superiority can come from economic profitability, status giving, etc. Compatibility is the degree to which an innovation is regarded as consistent with the existing sociocultural values, past experiences, and needs of potential adopters. Complexity is the degree to which an innovation is regarded as relatively difficult to understand and use. Trialability is the degree to which an innovation may be experimented with on a limited basis. Observability is the degree to which the results of an innovation are visible to others. Rogers (1995) calculated that 49 to 87 percent of the variance in rate of adoption is explained by these five attributes of innovations. The remaining variance is explained by type of innovation-decision process (individual choice, group choice, authority choice), type of communication channels in the innovation-decision process, nature of the social system and degree of change agents' efforts to promote the diffusion of an innovation. Extensive diffusion research conducted in Brazil, Nigeria and India showed that contact with change agents, knowledge of change agents and credibility of change agents were very important in explaining the rate of adoption of innovations (Rogers et al., 1970). Figure 6.1 gives an overview of variables affecting the rate of adoption of innovations.

Diffusion and adoption of Green Revolution technologies in developing countries

As mentioned agricultural technological innovations caused a rapid increase in agricultural productivity in the United States of America during the 1950s and 60s. The same methodology of technology-led development was replicated in developing countries in the 1960s and 70s and became known as the Green Revolution. A rapid increase in agricultural productivity was very necessary in these countries because in years with adverse rainfall many developing countries suffered from insufficient national food production. The introduction of many Green Revolution technologies such as High Yielding Varieties (HYV) and mineral fertilizers, facilitated by credit, information and orderly supply, was only a partial success as measured by observed rates of adoption (Feder et al., 1981).

The partial success of Green Revolution technologies in developing countries has been a subject of considerable interest in empirical economic research (Feder et al., 1981). Economic characteristics of alternative agricultural technologies were given a lot of attention. Schutjer and Van Der Veen (1977) mentioned efficiency, factor intensity, complexity and divisability as important characteristics. The efficiency of an agricultural technology is based on the cost/benefit ratio. Factor intensity is the degree to which an agricultural technology requires the use of factors as labour, capital and land. Complexity is the degree of consistency with existing practices or inconsistency due to new and complex concepts. Divisability points to the scale of required utilization and to the size of initial investment. Economic constraints to the adoption of agricultural technologies can be size of land holding, tenancy (tenants versus landlords), labour availability, capital (credit) availability, functioning of product and input markets, prices of products and inputs, risk level and uncertainty of profits and access to inputs and markets. In addition to these economic constraints Schutjer and Van Der Veen (1977) also mentioned that agricultural technologies are sometimes not suitable for the specific agroclimatic conditions facing the farmers.

Feder et al. (1981) in addition drew the attention to sequential patterns in adopting components of a new technological package, e.g. first adoption of HYV's followed later by adoption of mineral fertilizers.

That part of empirical economic research which investigated factors affecting adoption placed more emphasis on understanding the socioeconomic and agroclimatic context of technology diffusion and less on personal characteristics of the farmer and his family (Schutjer and Van Der Veen, 1977).

Diffusion and adoption of technologies from FSRE programmes

Investigations of reasons behind low or unequal adoption rates of Green Revolution technologies in developing countries led to new insights. One main insight was that agricultural research stations often developed recommended innovations with very little knowledge of the farmers for whom the recommendations were intended. These innovations were thus often not appropriate for the conditions of the utilizer. Agricultural research could be improved through incorporating the needs and conditions of farmers from the start of the research process (Röling et al., 1976). This idea was first taken up by international agricultural research institutes and gradually became also more important in national agricultural research institutes of developing countries. A research methodology for understanding the real-world economic systems that farmers operate was developed and became known as Farming Systems Research (FSR). The role of FSR is complementary to commodity research in the development and dissemination of relevant improved technologies and practices, and in the provision of conditions conducive to the adoption of technologies already available (Norman and Collinson, 1985).

A closer look at farmers circumstances and characteristics reveals inevitable variability. FSRE programmes, which integrate extension activities with FSR, must therefore recognize diversity in farming systems in developing appropriate technologies for different types of farmers on the basis of gender, social, physical and biological considerations (Wotowiec et al., 1986). FSRE methodologies classify farms and/or farmers with roughly homogeneous farming systems and for which an improved technology meets its biophysical and socioeconomic requirements for adoption into recommendation domains. These recommendation domains may or may not coincide with diffusion domains, which are interpersonal communication networks through which newly acquired knowledge of agricultural technologies flows naturally. In this way FSRE was regarded as a highly efficient method for enhancing technology innovation in agriculture for all strata of a community (Hildebrand, 1985).

To improve the adoption of agricultural innovations, FSRE methodologies must examine carefully the interaction between characteristics of the technology and characteristics of the farmers and farming systems that might accomodate the technology (CIMMYT, 1993). The selection of a technology for on-farm research has to be based on a ranking of problems expressed by farmers and an evaluation of possible solutions. This evaluation investigates the probability that a technology will function under the farmers circumstances, the profitability, the compatibility with the farming system, the contribution to reducing risk, the institutional support needed, the ease of testing by farmers and the ease of carrying out the experimental programme (Tripp and Woolley, 1989). Factors which influence adoption are for example the labour implications of a technology, allocation of household labour over the year, risk aversion by farmers, variability in prices of products and inputs, the efficiency of input and product markets and type of farming system (CIMMYT, 1993).

A good understanding of characteristics of farmers and farming systems and a good selection and evaluation of technologies needs proper participation of farmers from all strata at each stage of the technology development process. A major critique of FSRE methodologies has been that participation of farmers and so also the influence of farmers' knowledge and research activities was insufficiently incorporated in the technology research process (Okali et al., 1994).

New methodologies such as Farmer-First-and-Last (Chambers and Jiggins, 1987) and Participative Technology Development (Haverkort et al., 1988) were advocated to overcome this shortcoming of FSRE methodologies. Also FSRE practitioners looked for ways to include farmers as partners in the research-extension process (Galt and Mathema, 1987). Some examples of FSRE programmes with a greater emphasis on participation by farmers (Rhoades and Booth, 1982; Ashby, 1986; Kean, 1988; Norman et al., 1988) show that proper participation of farmers is also possible within the FSRE concept.

Adoption of fertilizer use by African farmers

Almost all current studies on adoption of fertilizer use by farmers in Africa concentrate on the socioeconomic characteristics of households in relation to adoption. Most of these studies confirm the findings of Rogers (1995) that education, social status, farm size, social participation, farm income, extension officer contact, mass media exposure and opinion leadership are positively correlated with the adoption of agricultural innovations by farm households. In addition fertilizer adoption studies in Nigeria (Abalu and Yayock, 1980; Daramola, 1989) showed that low adoption rates were also due to crop-fertilizer technologies being inappropriate to the existing farming systems and to institutional constraints in the supply of fertilizers to farmers. A fertilizer adoption study in Kenya (Mbata, 1997) showed that economic factors, especially profitability, were as important as sociological factors. In Malawi it was found that adoption of fertilizer use was influenced by type of crop, type of farming system, type of cultivar, access to credit, off-farm employment opportunities and labour availability (Green and Ng'ong'ola, 1993).

A study on the adoption of a technological maize package from an extension project by Sasakawa Global 2000 (SG2000) in Northern Tanzania showed that, as in the example from Feder et al. (1981), farmers adopted first improved seeds and then fertilizers in a stepwise process. The survey in 1993 revealed that 30% of farmers in Arumeru and Babati districts, Arusha region, used improved seeds in combination with fertilizers, 20% only improved seeds, 10% only fertilizers and 40% none of these two inputs (Nkonya et al., 1997). This study did not mention that SG2000 had locally created an institutional paradise by physically delivering the recommended package to the farmers on an initially 100% credit basis while allowing interest-free repayment either in cash or kind at the end of the agricultural season (Putterman, 1995). Only this can explain why farmers adopted recommended technologies with a Value Cost Ratio (VCR) of less than 2 (only fertilizers or only improved seeds) or just equal to 2 (fertilizers in combination with improved seeds). A VCR (additional benefits divided by the additional costs) of 2 is widely regarded as the minimum level acceptable to farmers (FAO, 1989). When farmers found out that SG2000 was pulling out after the third programme year they did not repay their credit anymore (Putterman, 1995). After the exit of SG2000 in 1993 farmers were left in the hands of private traders while IMF/World Bank reforms were increasing the gap between farmgate prices for inputs and crops. The Kilimo/FAO Plant Nutrition Programme in Arusha region noticed in their maize fertilizer demonstrations on farmers fields that the average VCR for fertilizer use declined from 2.8 in 1990/91 to 0.7 in 1993/94 (Jasperse, 1995). The impact of SG2000 seems to be nullified due to absence of institutional credit, poor availability of inputs in villages and ever decreasing VCR's for input use in maize (Putterman, 1995).

The rice-urea technology FSRE process in Sukumaland

The FSR Project Lake Zone followed the CIMMYT approach to FSRE. The first step in this approach is diagnosis through reviewing secondary data and conducting an informal survey (rapid rural appraisal), followed by a formal survey with a questionnaire. The information from the diagnosis is used in planning an on-farm research programme. The experimental results from the first year form important information for planning research in subsequent seasons. Further diagnostic work continues during the experimentation phase. After farmer assessment, agronomic evaluation and economic analysis of the experimental results from all seasons one could make recommendations to farmers. The results from on-farm research can also be used for planning future on-farm or on-station research, or as information to policymakers regarding input supply, credit regulations or institutional support (CIMMYT, 1988).

Diagnostic activities in relation to rice cultivation

In 1989 the FSR Project Lake Zone conducted an informal survey (rapid rural appraisal) in six villages of Maswa district and four villages of Meatu district. Such a diagnostic activity was urgent because a review of secondary data showed that there was very little agricultural background information available for these two districts. The main findings of the group discussions with farmers in these villages were that the farming systems were characterized by unreliable rainfall, extensive crop and livestock production, increasing population densities and degenerating productions of cotton, the main cash crop, due to unfavourable relations between input costs and producer prices. Farmers in the two selected villages from northwestern Maswa district appeared to have substituted rice for cotton as main cash crop. Apart from that, rice also proved to be the main food crop in these villages. Farmers stated that main constraints in rice production were weeds, high input costs (herbicides, fertilizers), non-availability of inputs and restricted access to suitable land for rice cultivation. The slight use of mineral fertilizers, especially ammonium sulfate, in rice had almost disappeared due to high fertilizer prices and availability problems. Only very few farmers applied farmyard manure to their rice fields due to labour constraints and transport problems (FSR Project Lake Zone, 1989).

The informal survey was followed by a formal survey in 1990 to verify and quantify the information from the mainly qualitative informal survey. A total of 284 households from eight villages were visited with questionnaires. The collected household data formed a basis for socioeconomic stratification. Access to oxen and ploughs turned out to be the main differentiating factor between households (Bantje, 1991). During 1990/91 on-farm rice research in two villages from northwestern Maswa district was combined with a household survey, covering a total of 65 households, which concentrated on rice management practices. The survey revealed that access to oxen and ploughs influenced many aspects of rice cultivation. Households stated that weeds, water problems, labour problems and pests were the main constraints to rice production. Soil fertility problems were not mentioned as a main constraint and this explains partly why only 6% of the households used mineral fertilizers in rice and only 2% applied farmyard manure to rice fields (Meertens and Ndege, 1993). A rapid rural appraisal in 12 villages scattered over neighbouring

Mwanza region during 1994 showed, however, that there low soil fertility was also regarded as a main constraint to rice production next to weeds, input problems and pests (Meertens and Lupeja, 1996).

Experimental on-farm activities

The constraints to rice production mentioned by farmers during the informal survey were subsequently analysed in more detail by the project team. Researchable issues were selected and possible solutions were evaluated by the researchers according to the criteria identified by Tripp and Woolley (1989) mentioned above. No viable solution was found for the weeding problem in rice. Simple cost-benefit calculations showed that the use of the available herbicides was not profitable for rice growing households. Introductions of ox weeders or hand implements for weeding rice were hampered by the fact that most farmers broadcast their rice fields and do not plant in narrow rows (Enserink et al., 1994b). During the village group discussions, farmers had also complained about declining rice yields. Farmers had been cultivating rice almost continuously on the same fields with very little use of fertilizers and farmyard manure. The project team thought that the declining rice yields might be attributable to a decrease in soil fertility. This hypothesis was supported by observations of mineral deficiencies, especially yellowing, in rice fields during the informal survey (Enserink et al., 1994a).

To test the hypothesis of low soil fertility, the FSR project conducted a diagnostic on-farm rice fertility trial in northwestern Maswa district. Rice has in comparison to sorghum, cotton and maize, a better control of weeds and a much higher return to family labour (Enserink et al., 1994a). So the rice production system was regarded as most suitable for efficient fertilizer use.

The main objectives of the trial were to monitor farmers' rice management practices, to test if use of nitrogen and phosphorus fertilizers and farmyard manure could significantly increase rice yields, and to test if the use of these (in)organic fertilizers would be economical. Farmyard manure was included as a treatment because about half of the households in Maswa district own cattle. Urea was chosen as nitrogen fertilizer due to its high nitrogen content and therefore lower transport costs. Triple Super Phosphate (TSP) was the only available phosphorus fertilizer. No potassium treatment was included because rice is cultivated on clayey soils which normally contain sufficient amounts of available potassium for rice production. Relatively low doses of nitrogen (30 kg N ha^{-1}), phosphorus (20 kg P_2O_5 ha^{-1}) and farmyard manure (5 tonnes ha^{-1}) were applied, due to recognized cash and labour constraints at the household level. Many households face cash flow problems throughout the agricultural season. Labour constraints are especially severe at weeding and harvesting. The trial was conducted during 1989/90 in two villages with three collaborating households in each village. Treatments were superimposed on farmers' rice management practices. Trial sites were visited each week by the responsible researchers in collaboration with the village extension workers. Results showed that the use of a low dose of urea at tillering gave a high and statistically significant increase in rice yield and was far more economical than the other treatments (Meertens et al., 1991).

The promising results of the diagnostic on-farm rice fertility trial encouraged the project team to continue with urea on a wider scale in the following season. For this a verification test was conducted in the same two villages during 1990/91. The low dose of 30 kg ha^{-1} urea-nitrogen was applied to 23 rice fields with different soils, differing water and tiller conditions at urea application, different positions on the slopes and different cultivars. The application of urea gave again a high increase in rice yield and proved to be economical under all circumstances tested. The enthusiastic reactions from farmers to the use of urea in rice prompted the project to execute a pre-extension campaign in the same two villages during 1991/92. A total of 150-200 households agreed to participate and data were collected from 120 fields selected from several valleys at different positions along the slopes. Urea could only be applied to 30 fields because farmers failed to plant rice in the other fields due to drought. The agricultural and economic performance of urea in the remaining fields was, however, very similar to the verification test (Enserink et al., 1994b). In 1992/93 the pre-extension campaign was repeated in two villages in neighbouring Kwimba district of Mwanza region, the new target area of the FSR Project Lake Zone in Sukumaland. A total of 138 fields were selected from several valleys at differing positions along the slopes. Urea could only be applied to 46 fields because farmers failed to plant rice in the other fields due to drought. The effect of urea application was less than in previous seasons for the same reason. Urea, however, still increased rice yields significantly and economically.

The Kilimo/FAO Plant Nutrition Programme used the rice-urea technology in an extension campaign in Mwanza region during 1994/95. A total of 160 households were selected from 26 villages scattered over Mwanza region. Due to good rainfall conditions urea could be applied to 157 fields of which 155 were finally harvested. The results showed that the application of urea was profitable in 82% of all fields irrespective of variations in soils, rainfall, positions along the slope and cultivars. The same programme conducted a rice NP-level on-farm trial in Sengerema district of Mwanza region during 1995/96. The objectives of this trial were to compare the low dose of nitrogen (30 kg N ha^{-1}) in the form of urea with higher doses of nitrogen and to detect any phosphorus deficiency in this part of Sukumaland. A total of 45 fields were selected from three villages but only from 15 fields results were obtained which were not affected by drought. These results showed that the low dose of nitrogen performed better, both agronomically and economically, than the higher doses and that there was no serious deficiency of phosphorus. More details of all above mentioned rice-urea on-farm activities are already provided in Chapter 5.

Recommendations to farmers and policymakers

The results of the verification test in 1990/91 provided a basis for incorporating preconditions concerning the efficient use of a low dose of nitrogen at tillering in rice. It was advised to apply urea only to established (weeded, thinned and gap filled) rice fields with water depths less than 15 cm and not more than five tillers per plant at urea application (Meertens et al., 1992). These findings of the verification test were confirmed by results from both pre-extension campaigns (Kajiru, 1993 and 1994). At this stage the project team felt confident to make a provisional recommendation to farmers on the efficient use of urea in rice. An extension leaflet in Kiswahili was prepared in 1994 (FSR Project Lake Zone, 1994).

Urea was not available in Maswa district during the first years of the on-farm experiments. Recommending the use of urea to farmers was inappropriate under such circumstances. A field day was organized for policymakers from the regional cooperative union and Maswa district during harvest time of the 1990/91 verification test to show the performance of urea in rice. It had been hoped that this would solve the availability problems of urea in Maswa district (Meertens et al., 1992). In fact it was not until 1994 that the Maswa Rural Development Project made 80 tonnes of urea available for farmers in Maswa district (Heemskerk, 1996). Urea was also not available in Mwanza town during the 1994/95 season. Only halfway 1995 the Tanzania Fertilizer Company (TFC) brought 100 tonnes of urea to their Mwanza depot, possibly as a result of requests by the Kilimo/FAO Plant Nutrition Programme team in Mwanza region.

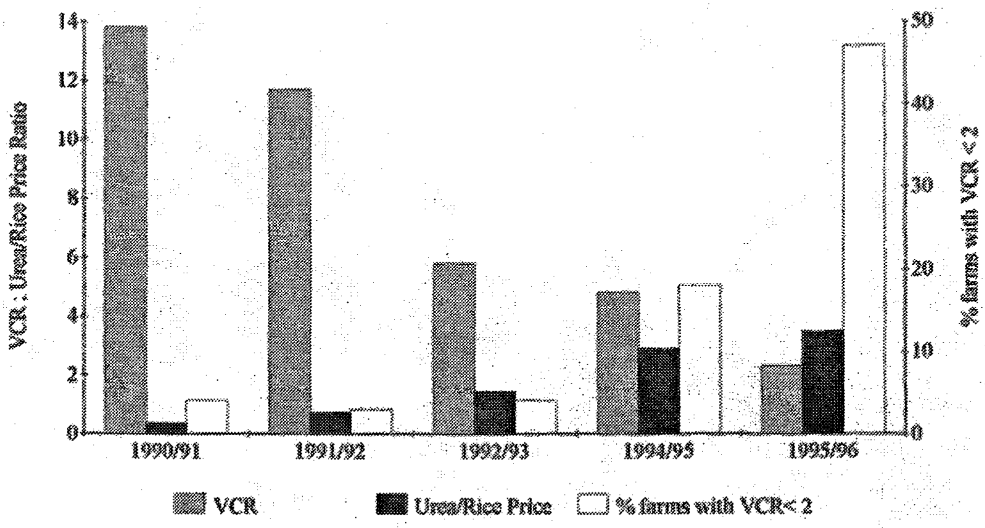
Factors explaining non-adoption of rice-urea technology

Almost all farmers were impressed by the performance of urea in rice during the on-farm activities from 1989 till 1996, but very few farmers actually adopted this rice-urea technology. After the 1989/90 diagnostic on-farm rice fertility trial in northwestern Maswa district farmers asked the researchers where they could get urea (Meertens et al., 1991). During the evaluation of the 1990/91 verification test farmers asked if the FSR project could supply them with urea. One remaining bag of urea was sold quickly to a farmer who applied it to his rice fields. Farmers started to lose interest when they found out that the project could not guarantee the supply of urea (Meertens et al., 1992). Also the majority of farmers participating in the pre-extension campaigns in Maswa and Kwimba districts indicated that they intended to buy urea when it could be made available at the village level. Farmers who had been involved in the rice on-farm activities between 1989 and 1992 said that problems with availability of urea and failures to plant rice due to drought had prevented them from adopting this technology so far (Bunyecha, 1994a). Farmers participating in the 1992/93 pre-extension campaign mentioned that availability problems and high prices of mineral fertilizers were the main constraints to adoption of the rice-urea technology. Minor constraints were lack of cash, risk associated with drought and lack of extension services on the use of mineral fertilizers (Bunyecha, 1994b). A later survey in 1995 showed that high prices of urea continued to block adoption by farmers whenever urea was made available at the village level (Kajiru, 1995). The evaluation of the 1994/95 extension campaign in Mwanza region showed that farmers were not familiar with urea and with mineral fertilizer applications in flooded fields. Farmers expressed their concerns about the availability and high price of mineral fertilizers. A substantial number of farmers indicated that they often faced cash problems and that there were no credit facilities available in their villages (Lupeja and Meertens, 1996a).

In Maswa district farmers had not started to use urea in rice after the on-farm activities of the FSR project (Mshumbusi, 1996). In Mwanza region the Kilimo/FAO Plant Nutrition Programme did not record great increases in urea use after it became available in Mwanza town halfway 1995. The greater part of the urea was bought by farmers growing horticultural crops (tomatoes, onions, cabbages) in the vicinity of Mwanza town. There was no need to conduct more detailed adoption surveys on the use of urea in rice, due to the obvious non-adoption in entire Sukumaland.

In the following we take a closer look at the factors affecting the adoption of the rice-urea technology by farmers in Sukumaland. Relevant factors mentioned by

Figure 6.2
Value cost ratios, urea/rice farmgate price ratios and percentages of farms with value cost ratio below 2 for application of 30 kg N ha^{-1} in rice in the form of urea during on-farm activities in Sukumaland, Tanzania, between 1990 and 1996



Source: Meertens et al., 1992; Kajiru, 1993 and 1994; Lupeja and Meertens, 1996a and 1996b

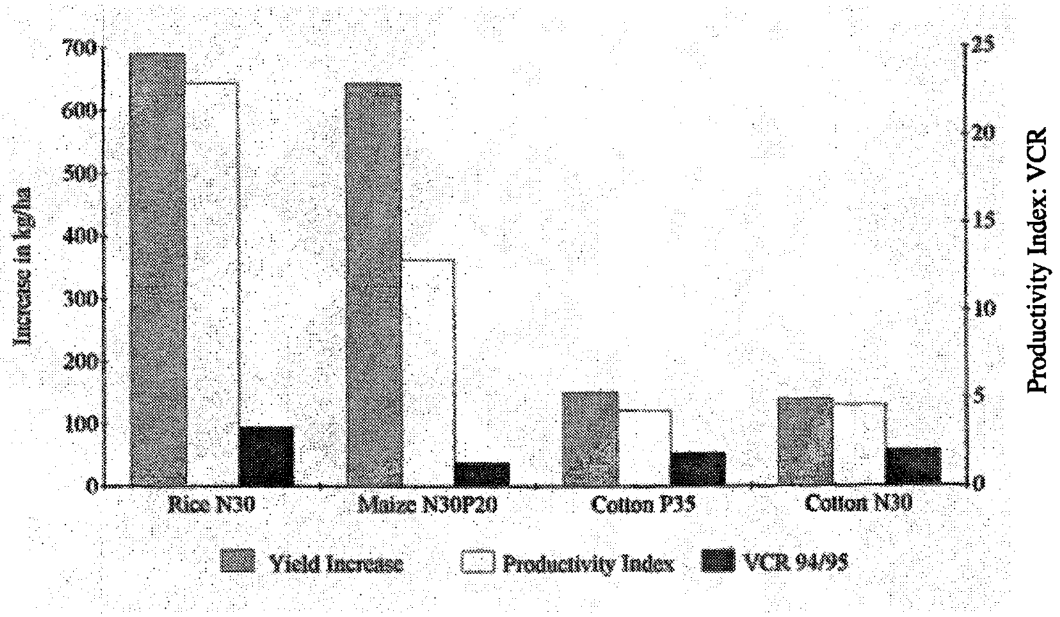
Rogers (1995), Schutjer and Van Der Veen (1977), and CIMMYT (1993) are for that matter grouped according to type of technology, profitability, compatibility with farming systems and institutional setting.

Type of technology

The rice-urea technology introduced by the FSR project in Sukumaland is not a complex type of technology. Mineral fertilizers, in particular ammonium sulfate and TSP, had already been used by farmers on crops such as cotton, maize and rice (FSR Project, 1989). Although urea is a relatively new type of nitrogen fertilizer in Sukumaland, the application of urea is easy because the fertilizer is broadcast directly into flooded rice fields. Farmers stated that application of urea in rice could easily be done by children (Bunyecha, 1994b).

The rice-urea technology is highly divisible because farmers can decide to apply urea first only to a small rice field. Due to the easy concept of this technology farmers can easily experiment with it in their rice fields. The effect of the technology is clearly observed by farmers because rice plants develop more tillers, become greener and reach higher lengths. The relatively low dose of nitrogen from the cheapest source of nitrogen, urea, reduces the initial investment costs and makes this technology more accessible to the lower strata of the farming community. All rice growing households could be regarded as one recommendation domain.

Figure 6.3
Average increase in yield, productivity index and value cost ratio (1994/95 farmgate prices) for use of mineral fertilizers in rice, maize and cotton in Sukumaland, Tanzania



Source: Lupeja and Meertens, 1996a; Mowo et al., 1990 and Chapter 5

Profitability

A very important aspect is the relative advantage of this technology in comparison to the current practice of the farmers, which is almost no use of organic or inorganic fertilizers. The efficiency or profitability of this technology is reflected in the Value Cost Ratio (VCR, the additional benefits divided by the additional costs). As mentioned the VCR level should not be lower than 2. Figure 6.2 shows that average VCR levels were much higher than 2 in the first years of the on-farm activities but were very close to 2 by the 1995/96 season. The main reason for this huge drop in VCR levels is the enormous increase in the ratio between farmgate prices of urea and rice in the 1990-96 period (Figure 6.2). To encourage the use of mineral fertilizers the Tanzanian government had been subsidizing this agricultural input during the 1970s and 1980s. By 1988/89 mineral fertilizers had an implicit subsidy of up to 80 percent (World Bank, 1994). IMF/World Bank reform programmes, however, forced the government to phase out the subsidy gradually from 70 percent in 1990/91 to zero in 1994/95. Figure 6.2 shows that farmgate prices of rice could not keep up at all with these increases in farmgate prices for urea. As a result the percentage of cases with VCR levels lower than 2 increased from 3-4% in 1990-93 to almost 50% in 1995/96 (Figure 6.2). In other words almost half of the households who applied urea in one of their rice fields during 1995/96 did not get a satisfactory profit from this technology.

Apart from comparing the rice-urea technology with the current practice in rice you can also relate its performance to alternative use of mineral fertilizers in crops other than rice. Maybe it would be a better option to invest money in applying mineral fertilizers to other important crops such as cotton and maize. The efficiency of a certain fertilizer-crop combination can be evaluated in different ways. One way is to look at the absolute increase in crop production. Other ways are to calculate the VCR, or the Productivity Index (PI), which is the increase in kg crop produce per kg applied plant nutrient (FAO, 1989). Figure 6.3 presents a comparison of the rice-urea technology with other fertilizer-crop combinations in Sukumaland. For the calculation of the VCR's we used the farmgate prices for crops and fertilizers of the 1994/95 season. Figure 6.3 shows that the rice-urea technology was then superior to alternative uses of mineral fertilizers in maize and cotton in all aspects. For farmers the most decisive aspect is the comparison of value cost ratios. The use of fertilizers in maize is not profitable due to low farmgate prices for maize. For cotton low productivity indices of fertilizer use in this crop are the main reasons behind the low VCR's.

Figure 6.3 does not include the use of mineral fertilizers in horticultural crops due to lack of available data. Observations in the vicinity of Mwanza town showed that many farmers were using mineral fertilizers in horticultural crops while only very few were applying urea in their rice fields (Meertens and Lupeja, 1996). The high demand for horticultural crops in Mwanza town makes it profitable to use fertilizers and apparently more profitable than applying fertilizers in rice fields. The use of mineral fertilizers in horticultural crops is, however, restricted to the vicinity of Mwanza town or other towns: absence of reliable markets and transport for horticultural products in other parts of Sukumaland greatly reduce the use of fertilizers in horticultural crops there.

Compatibility with farming systems

The rice-urea technology does not require a considerable increase in labour from the farming households. The application method of broadcasting urea in flooded rice fields restricts the involved labour inputs to less than a day for an entire hectare of rice. Higher labour inputs are, however, needed from the households for harvesting the increased rice yields. Farmers did not complain about this during the evaluations of the rice-urea on-farm activities in Sukumaland, even though labour rather than land is regarded by farmers as the main limiting production factor (FSR Project Lake Zone, 1989). The low labour intensity of the rice-urea technology makes it therefore highly compatible with the farming systems in Sukumaland.

The application of urea in rice requires capital in the form of cash from the households. The low dose of nitrogen, the absence of other nutrients and the choice of urea as the cheapest source of nitrogen have kept the amount of cash involved to a minimum level. The substantial price increase for a bag of urea between 1990 and 1996 made, however, the initial investment costs 25 times higher. For small households, who form about one third of the total number of households, these higher initial investment costs were becoming problematic. For small households in Mwanza region it was calculated that the purchase of the recommended amount of urea for one acre of rice in 1993/94 needed one quarter of the available cash for expenditures other than necessary items like food, clothes, soap, school fees and medicines (Meertens and Lupeja, 1996). The investment in urea has furthermore competition from alternatives such as purchasing other agricultural inputs like storage insecticides for maize. It can also be more profitable to use that money for small trading, for purchasing a bicycle, hiring a plough or for labourers to do weeding in their fields.

Unreliable and in some years inadequate rainfall makes agriculture in Sukumaland a risky enterprise. Farmers use several strategies (staggered planting, mixed cropping/intercropping, use of more drought tolerant crops, cultivation on ridges, accumulating water in bunded rice fields, keeping large livestock herds) to reduce the level of risk in their farming systems (Meertens et al., 1995; Dercon, 1996). The uncertain outcome of their efforts makes farmers reluctant to use agricultural inputs in the production of crops. These investments can turn into considerable losses of cash when crops are hit by prolonged droughts. Low use of agricultural inputs is thus a way of minimizing financial risk. The use of mineral fertilizers can even have adverse effects on crop production when prolonged droughts follow after application. In such circumstances high fertility in the soil can aggravate the drought (Brouwer et al., 1993). Application of mineral fertilizers can then lead to lower germination rates in case of basal applications of phosphorus and nitrogen or to reduced generative growth in case of topdressing of nitrogen. Broadcasting urea to flooded rice fields at tillering has the advantage that dry spells of one to two weeks can be tolerated with the consumption of standing water in the rice field. For basal and topdress applications of mineral fertilizers to cotton and maize the effects of dry spells of one to two weeks can, however, already be disastrous. These differences in efficiency of fertilizer use are reflected in the productivity indices for rice, maize and cotton in Figure 6.3. Dry spells longer than two weeks and frequent returning of dry spells will, however, eventually also lead to losses of cash when farmers have applied urea in rice. Figure 6.2 shows that the risk of losing money (VCR<2) had become serious in 1995/96 due to a gigantic deterioration in the ratio between urea and rice farmgate prices.

The rice-urea technology does not involve major changes in the cultivation of rice other than the application of urea. The good performance of urea in the on-farm activities of the FSR project was accomplished with local rice cultivars. So no improved rice cultivars have to be bought by farmers for the application of a low dose of nitrogen. The low incidence of pests and diseases in Sukumaland rice (Mashaka et al., 1992) does also not necessitate investments in agrochemicals. No drainage is needed prior to urea application because water depths up to 15 cm at application still give satisfactory increases in rice yield (Meertens et al., 1992). Applications of fertilizers in maize and cotton on the other hand do require additional changes in the cultivation (planting in lines with recommended spacing, monocropping) and in use of inputs (improved cultivars, agrochemicals). Fertilizers are here components of recommended packages with much higher initial investment costs than the rice-urea technology (Meertens and Lupeja, 1996).

Diagnostic activities in Sukumaland showed that farmers regard weeds, high input prices and problems with input availability as the main constraints in rice cultivation (FSR Project Lake Zone, 1989; Meertens and Lupeja, 1996). Low soil fertility was also regarded as a problem, especially in Mwanza region, but always as a secondary constraint to rice production. Rice yields in Sukumaland are in the upper range of reported yields from similar rice cropping systems in Asia (see Chapter 4) and most farmers in Maswa district appear to be satisfied with these yield levels (Mshumbusi, 1996). In northwestern Maswa district rice is the main food and cash crop. In many other parts of Sukumaland rice is also important as a food and cash crop but often comes second or third after cassava, maize or cotton (Meertens et al., 1996; Meertens and Lupeja, 1996). These lower rankings of the soil fertility problem and the crop rice by farmers in parts of Sukumaland had most probably an effect on the adoption rate of the rice-urea technology.

Institutional setting

Input and output markets

Prior to IMF/World Bank reform programmes input and output markets in the agricultural sector were controlled by the Tanzanian government. Important agricultural inputs were distributed to the villages by regional, government controlled cooperatives. Farmers could obtain these subsidized inputs from the village branches of the regional cooperatives on a credit basis. The reform programmes after 1986 gradually reduced the influence of government controlled institutions engaged in input and output markets in the rural sector. The supply of agricultural inputs and the purchase of agricultural products had to be liberalized. Government controlled institutions had to be replaced by private traders (World Bank, 1994).

Liberalization of input supply worked quite well in areas with high demand for inputs and favourable road networks like Iringa, Mbeya and Ruvuma (World Bank, 1994). In the Mwanza and Shinyanga regions of Sukumaland private traders were not able to quickly take over the role of the regional cooperatives, due to poor roads and low demand for inputs. Only very few private traders engaged themselves in input supply in Mwanza region. Most of them had no transport facilities and limited capital so that they were not able to reach the majority of villages. A survey in 1994 showed that many important agricultural inputs were completely unavailable at the village level in Mwanza region (Meertens and Lupeja, 1996). Capital limitations and uncertainty about sales due to unreliable rainfall forced private traders to keep only small stocks of inputs, which they replenished when necessary. No inputs were supplied to farmers on a credit basis due to the relatively small working capital of the private traders. With the disappearing credit facilities of the regional cooperative, farmers in Mwanza region were only left with informal credit facilities which have high interest rates (10-20%) per month (Meertens and Lupeja, 1996).

The very bad condition of rural roads in Sukumaland at the end of the rainy season discourages private traders to buy agricultural products from farming households in the more remote villages. The very few traders who reach these villages are able to set very low crop prices due to the absence of competition. Most farmers are completely broke at the end of the rainy season and are forced to accept the offered low prices. The low level of household cash income and the absence of credit facilities thus prevent farmers in remote villages from purchasing agricultural inputs (Meertens and Lupeja, 1996).

Extension and research services

The rice-urea on-farm activities in Sukumaland were conducted in close collaboration with village extension workers after joint planning sessions with district and regional extension officers. The village extension workers had, however, several other duties next to the rice-urea on-farm activities. They were in fact quite occupied with tasks related to the Training and Visit (T&V) extension system which started in Mwanza and Shinyanga regions around 1990. This T&V system requires that each village extension worker advises eight groups of about 15 farmers each fortnight while supervising small trials/demonstrations in the fields of these farmers. The extension messages are long-term recommendations from research stations in which the village extension workers are trained in a systematic, top-down approach. For new recommendations effective links with research have to be established (Benor and Harrison, 1977). A long-term recommendation for soil fertility improvement in Sukumaland is the use of farmyard manure (Meertens et al., 1995) and this became one of the main topics in the T&V system practised in Sukumaland. The new recommendation to use urea in rice got little attention and was not incorporated in the small trials/demonstrations in farmers' fields due to the T&V headquarters' preference for the use of farmyard manure. The FSR project stopped their field activities in Maswa district in 1992 and thereafter no follow up activities related to the rice-urea technology were organized by the district extension authorities (Heemskerk, 1996). The extension leaflet on urea use in rice produced by the FSR project in 1994 was distributed to all relevant institutions in Sukumaland but was only actively used by the Kilimo/FAO Plant Nutrition Programme in Mwanza region. For many farmers urea was new and also the application to flooded fields was a new technology to them. The absence of demonstrations and information from extension officers on the rice-urea technology discouraged the adoption of this technology by farmers.

The FSR Project Lake Zone formed a department at the zonal Ukiriguru agricultural research and training institute and was much better funded by donors than the commodity research departments. This created competition and friction instead of collaboration between FSR and commodity teams. Similar experiences were observed in other East African countries (Enserink, 1995). In the beginning of the 1990s international donors shifted their attention from FSR to sustainable agriculture. Funding of the new activities related to sustainable agriculture were often channeled through the commodity departments. Priority setting in research activities at these departments were strongly influenced by the presence of funds. While the FSR Project Lake Zone pursued the rice-urea technology, other departments were investigating the use of organic fertilizers (green manures, rice husks, multi-purpose trees) in rice. In one activity the effect of rice husks ash on rice yield was compared with an application of 45 kg N ha^{-1} in the form of ammonium sulfate and not urea (Bagarama et al., 1995). This clearly shows that there was no proper planning of a joint research agenda between FSR and commodity teams. There was no uniformity in messages related to soil fertility improvement in rice and this caused confusion among farmers. Very low adoption rates are observed in Sukumaland for any of these messages (Meertens and Lupeja, 1996).

Discussion and conclusions

This paper has shown that the rice-urea technology developed by the FSR Project Lake Zone in Sukumaland was not adopted by farmers due to a number of factors. In the beginning of the 1990s this technology was highly profitable but could not be adopted because urea was not available in the villages. After 1990 IMF/World Bank reforms reduced the VCR level from more than 10 to just above 2 in 1995/96 due to a gigantic increase in the ratio between farmgate prices for urea and rice. When urea became available in Maswa district around 1994 and in Mwanza region halfway 1995 it was only seldomly bought for application in rice. Increased risk of losing cash and increased height of initial investment costs due to higher urea prices deterred farmers from adopting the rice-urea technology. The availability of urea at the village level remained very poor because IMF/World Bank reforms left the supply of agricultural inputs in the hands of private traders with limited capital and no means of transport. These private traders were further not able to provide urea on a credit basis to households with limited cash. The poor road network in Sukumaland aggravated the problems in supply of inputs and sale of crops by farmers. The decreased profitability of the rice-urea technology diminished the competition with alternative uses of household cash such as purchase of agricultural inputs for other crops or livestock, trading, hiring labourers for weeding and buying a bicycle or a plough. Households' decisions not to invest scarce cash in the rice-urea technology were also influenced by perceived lower priority of the soil fertility problem in the rice cropping system and/or lower importance of rice in the farming systems for many parts of Sukumaland. Adoption of the rice-urea technology was further hindered by lack of assistance from the extension service and by confusing messages from the research institute related to soil fertility improvement in rice. In fact non-adoption of the rice-urea technology in Sukumaland was mainly determined by adverse economic and institutional factors in a setting where agriculture is a risky enterprise.

Agricultural research methodologies like FSRE can potentially be highly efficient methods for enhancing technology innovation in agriculture for all strata of a community if institutional settings and government policies are conducive to adoption of these innovations. The example of the rice-urea technology in Sukumaland shows, however, that FSRE efforts can be completely nullified by adverse government policies and poor institutional settings. In that aspect there is no difference with the outcome of other approaches, as the SG2000 example in Northern Tanzania shows (Putterman, 1995). Agricultural policies from governments, international donors and international institutions like IMF and World Bank can hopefully be influenced through providing information on the effects of these policies in relation to adoption of agricultural innovations and performance of the agricultural sector in general. This paper can be seen as a partial attempt in that direction.

In addition, the FSRE methodology which led to the recommendation of applying a low dose of nitrogen in the form of urea in rice appears to have some shortcomings in the ranking of constraints felt by households. Woolley and Tripp (1994) argue that participation of farmers during diagnosis is well established but that participation of farmers during priority setting still needs to be developed. Farmers have different rankings of constraints than agricultural researchers, who place technical issues at a higher level. Full participation of farmers during priority setting will lead to a mutual understanding of common defined problems (Rhoades, 1994). The rice-urea technology in Sukumaland was, however, based on a priority setting dominated by researchers and policy makers. More interaction with farmers on this priority setting before the onset of the experimental phase would most probably have altered the ranking of priorities and increased the possibility of adoption of the tested technologies.

For effective adoption of agricultural technologies FSRE methodologies need strong and institutionalized links with the extension service, commodity research and policy makers. This paper has shown that FSRE methodologies can become fruitless without these links. The appointment of a so called Research Extension Liaison Officer (RELO) is, however, not enough. Links are especially needed at the level of policy makers (government and donors), to obtain a better coordination and integration of extension and research. Poor coordination among donors can lead to conflicting agricultural messages. In Sukumaland the T&V extension system sponsored by the World Bank advocated the use of farmyard manure in rice while the Dutch co-financed FSR Project Lake Zone recommended the application of urea in rice. Effective links between FSRE and extension service can be established better when the T&V or other type of extension service is more participatory and demand-driven as proposed for Tanzania by Van den Ban and Mkwawa (1997). According to Norman (1994), key factors in achieving constructive interactions between FSRE and commodity research are effective communication, trust and credibility. We would like to add to that a better coordination between donors so that funding of FSRE and commodity research produces complementary activities which will not confuse the farmers.

Notes

1 Kilimo is a short name for the Tanzanian Ministry of Agriculture and Cooperatives.

Acknowledgements

The rice-urea technology FSRE process involved many farming households, village extension officers, district/regional officers, and researchers from Ukiriguru Agricultural Research and Training Institute. All are thanked for their contributions to this process. Dr. Joost Brouwer is thanked for his useful remarks on earlier drafts.

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7 The Prospects for Integrated Nutrient Management for Sustainable Rainfed Lowland Rice Production in Sukumaland, Tanzania*

Abstract: The possibilities of integrated nutrient management for sustainable rice cultivation are investigated for rainfed, lowland rice in Sukumaland, northwestern Tanzania. Consumption of mineral fertilizers in rice there is very low due to availability problems and sharply increased prices of fertilizers. Use of locally available resources for soil fertility improvement is hampered by the additional inputs of farm household labour involved. High labour inputs per hectare lead to lower marginal and average products per hour of labour. Furthermore in semi-arid Sukumaland biomass production of green manures is seriously restricted by climate. The amount of kraal cattle manure is insufficient and half the households have no easy access to it. Studies of nutrient balances to assess present sustainability need to involve farmer participatory methods. Information from farmers and a nutrient balance calculation suggest that at present there is not yet an urgent need for improved integrated nutrient management in Sukumaland rice cultivation.

Key words: integrated nutrient management, rainfed lowland rice, nutrient balance, labour productivity

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* Submitted to *Agricultural Systems*

Introduction

The 1992 United Nations Commission on Environment and Development (UNCED) meeting in Rio de Janeiro increased the attention of donors and development agencies for the concepts of sustainable agriculture and environmental degradation in developing countries. In Western countries excessive use of biocides and (in)organic fertilizers had fuelled concerns about the sustainability of Western agricultural systems and their impact on the environment. These concerns influenced donors and development agencies and made them reluctant to stimulate the use of biocides and mineral fertilizers in developing countries. Some donors like The Netherlands reduced their grants and exports of mineral fertilizers to developing countries and opted for the Low External Input and Sustainable Agriculture (LEISA) policy (Donkers, 1993). Within the LEISA approach optimal use is made of locally available resources and limited external inputs are used as efficiently as possible (Kieft, 1992). An assessment of the rate of major nutrients depletion under agriculture in sub Saharan Africa (SSA) revealed widespread negative annual budgets for nitrogen, phosphorus and potassium (Stoorvogel and Smaling, 1990). Based on these results it is argued that the soil nutrient stock is gradually depleted to levels that can soon no longer sustain a still growing African population. Nutrient stocks can, however, be manipulated by farm households through management practices that save nutrients from being lost from the system (e.g., through erosion control or restitution of residues) or through measures that add nutrients from outside (e.g., application of mineral fertilizers). The efficient combination of these methods is called integrated nutrient management (INM) (Smaling et al., 1996). Pretty (1995) presents some successful examples of integrated nutrient management systems in developing countries but admits that these are still isolated instances. Adoption of INM requires increased inputs of labour, management skills and knowledge. Farmers must therefore invest in learning. The principal barrier to INM and LEISA in general is according to Pretty (1995), however, the absence of a favourable policy environment. Most policy frameworks still actively favour farming on the basis of external inputs and technologies.

During the 1970s SSA showed practically no growth in average incomes, and even an actual decline in per capita food production. International institutions like the World Bank and the International Monetary Fund (IMF) laid the blame mainly on the governments of the African states, accusing them of gross mismanagement, faulty exchange rate policies, excessive state intervention, unnecessary subsidies of urban consumers, extraction of high rents from rural producers and general corruption (Barratt Brown, 1995). Their central argument was that the state should withdraw from intervention in the economy and open up all economic activity, especially in agriculture, to market forces. Aid was only supplied to individual African governments which were prepared to adjust to the requirements of the international financial institutions (Barratt Brown, 1995). Such aid in the form of so called structural adjustment programmes started in Tanzania around 1986. The reform measures included a liberalization of the supply and pricing of agricultural inputs. In 1988/89 mineral fertilizers had an implicit subsidy of up to 80 percent. The reform measures forced the Tanzanian government to phase out the subsidy gradually from 70 percent in 1990/91 to zero in 1994/95 (World Bank, 1994). The significant increase in mineral fertilizer prices, while crop prices increased only slightly, led to a significant decrease in mineral fertilizer consumption and demand in Tanzania (FAO, 1997). The adverse circumstances for use of mineral fertilizers in Tanzanian agriculture encouraged farmers, researchers and policy makers to investigate the possibilities of alternatives for soil fertility improvement. Halfway the 1990s this led to a conducive policy environment for INM based technologies in Tanzania.

This paper discusses the cultivation of rainfed lowland rice in Sukumaland as a case study for investigating the possibilities of INM for sustainable rice production in Tanzania. Sukumaland forms the greater part of the Mwanza and Shinyanga regions in northwestern Tanzania. Rainfed lowland rice cultivation is important in most farming systems of Sukumaland for its contribution of food and cash to the households (Meertens et al., 1996). Between 1989 and 1994 the Farming Systems Research Project Lake Zone developed a rice-urea technology, involving the application of a low dose of nitrogen (30 kg N ha^{-1}) to rice plants at tillering, as a response to farmers' statements of declining yields in their rice fields (Enserink et al., 1994). The adoption of this technology was very meagre, mainly due to availability problems of urea in the villages and a decreased profitability of the rice-urea technology as a result of sharp increases in the farmgate price of urea (see Chapter 6). As a consequence, donors and government institutions engaged in research and extension on rice in Sukumaland shifted their attention to the possibilities of soil fertility improvement in rice fields with locally available resources. This paper gives an overview of recent on-farm and on-station research on soil fertility improvement with locally available resources in Sukumaland rice. Each type of technology is analysed according to its potential of adoption within the farming systems of Sukumaland. The relatively high labour requirements of many proposed methods involving locally available resources appear to be a serious constraint for adoption by households. A more detailed description of labour productivity with regard to these types of methods serves as an explanation for current low adoption rates. All this forces us to take a new look at the role of mineral fertilizers within the framework of INM in rice. The supplied nutrient balance for the rice cropping system assists in determining future directions of INM research for sustainable rice production in Sukumaland.

Setting of the rainfed lowland rice cropping system in Sukumaland

In Sukumaland average annual rainfall varies between 700 mm and 1000 mm. The rains normally start around mid-October and end by mid-May. The rainfall pattern is bimodal with peaks in November-December and March-April. The rainshowers are, however, very localized and unpredictable. Dry spells are common throughout the rainy season but are most pronounced during January (Meertens et al., 1996). Potential evapotranspiration rates of 4.5 mm day^{-1} occur during the rainy season (ICRA, 1991).

Sukumaland lies mostly between 1000-1300 m above sea level. The landscape is characterized by broad as well as narrow valleys separated by rocky hills that consist mainly of granitic and sometimes gneissic rocks. There are also some vast alluvial (fluvial and lacustrine) plains, derived from the same type of rocks. Typical soil catenas have developed in the granite and gneissic parent materials. The broad valleys are gently undulating to almost flat with alkaline, sandy clay hardpan soils as dominant soil types. Dominant soil types in the vast plains are dark cracking clays or calcareous, friable clay loams (Milne, 1947).

The cultivation of rice is very important in the broad valleys with dominant hardpan soils located in those parts of Sukumaland which receive more than 800 mm average annual rainfall (see Chapter 4). To catch and control the uncertain water supply farmers construct bunds around the rice fields in which runoff water accumulates. Infiltration rates are low due to the hardpan. However, cultivars with low water requirements are still preferred. The average yield of these tall, photoperiod sensitive *indica* cultivars is 2300 kg ha^{-1} in Sukumaland. Land preparation is done by ox plough or by handhoe. Transplanting is common in the more populated areas (population density 100-270 people km^{-2}) while broadcasting of seed dominates in the less populated areas (30-75 people km^{-2}). The main constraints to rice growing are weeding and water shortages. In Mwanza region low soil fertility is also regarded as a main constraint to rice production. The use of agricultural inputs is very low so that the cultivation of rice in Sukumaland is mainly based on family labour and land. The rainfed lowland rice system in Sukumaland is drought-prone and in one out of three years farmers fail to plant rice due to unreliable, low rainfall (see Chapter 4).

Research on the use of locally available resources for rice soil fertility improvement

Research on the use of locally available resources for rice soil fertility improvement in Sukumaland started in the 1940s on the shore of Lake Victoria at the Mwabagole rice station, a substation of the agricultural research station at Ukiriguru. Control yields under research station conditions were compared with the puddling in of green shoots of cassava tree (*Manihot glaziovii*) and cassia (*Cassia sp.*), about a month before transplanting, and with the application of farmyard manure. Results over two seasons showed that the puddling in of 10 tons cassava tree shoots ha^{-1} increased the average control rice yield of 4846 kg ha^{-1} by 1419 kg ha^{-1}. The puddling in of 10 tons cassia shoots ha^{-1} increased the rice control yield by 1649 kg ha^{-1} and the application of 10 tons farmyard manure ha^{-1} gave an increase of 881 kg ha^{-1}. The researchers argued that the additional labour involved in cutting, transporting and incorporating the green manures was well repaid by the increases in rice yield. On the other hand it was thought that the biggest advance in increasing rice yields would come from water control and supplementary irrigation (Doggett, 1965).

In the 1960s, 1970s and 1980s there was no further research in Sukumaland on the use of locally available resources for soil fertility improvement in rice due to the availability of relatively cheap mineral fertilizers. The complete withdrawal of subsidies on mineral fertilizers in Tanzania during the early 1990s gave a new impulse to investigations on the use of locally available resources. Examples of such research are the use of green manures and multi-purpose trees for soil fertility improvement in rice fields. One experiment involved the cultivation of *Sesbania sesban*, *Sesbania rostrata* and *Crotalaria ochroleuca* as a fallow crop for incorporation prior to rice transplanting. From the onset of rains in November until the transplanting of rice at the end of March the *Sesbania sesban* and *Sesbania rostrata* green manures were able to produce about 6 tonnes of fresh green matter ha^{-1} while *Crotalaria ochroleuca* reached a maximum of 8 tonnes ha^{-1}. No effect on rice yield could be established because the rice crop failed due to poor rainfall (Otsyina et al., 1994). Another experiment investigated the use of dried leaves from *Leucaena leucocephala* as green manure for incorporation in rice fields. The dried leaves were incorporated prior to rice transplanting and also 4 and 8 weeks after transplanting. Total applications of 3 and 6 tonnes dried leaves ha^{-1} were established and compared to control plots with no application. The experiment was repeated for two more seasons with the same treatments on the same plots. Average results from these three seasons showed that the application of 3 tonnes dried leaves ha^{-1} increased the average control rice yield of 2438 kg ha^{-1} by 580 kg ha^{-1} while 6 tonnes dried leaves ha^{-1} gave an increase of 760 kg ha^{-1} (Otsyina et al., 1995).

After consideration of the labour involved in transporting significant amounts of green matter to farms it was suggested to grow green manures on farm boundaries or on bunds between the rice fields. One experiment investigated the performance of fast growing nitrogen fixing trees on rice bunds as green manures for rice production, and as a possible fodder for livestock during the dry season. Seedlings of *Sesbania sesban, Sesbania macrantha, Sesbania rostrata* and *Leucaena leucocephala* were established on rice bunds with a spacing of 0.5 m. Between 1993 and 1995 there were four incorporations of *Sesbania sesban* and *Leucaena leucocephala*, three incorporations of *Sesbania macrantha* and only one incorporation of *Sesbania rostrata*. The total amount of fresh green matter applied between 1993 and 1995 is not clear from the reports but can be estimated to be in the range of 25-50 tonnes ha^{-1}. For the annual *Sesbania rostrata* it was 5.1 tonnes fresh green matter ha^{-1} (Otsyina et al., 1994). The effect from all incorporations of green manure on rice yield in 1995 were similar for all types of green manure. The control rice yield of 2433 kg ha^{-1} was increased by 1600-2000 kg ha^{-1} (Otsyina et al., 1995). No estimates were given for the labour involved in incorporating the green manures in these on-station experiments. However, the yield results encouraged the researchers to plan an evaluation of the use of green manures under farmers' conditions (Otsyina et al., 1995).

Green manures have been used by Chinese farmers for soil fertility improvement in irrigated rice fields for almost 3000 years (Greenland, 1997). On a more limited scale green manures are also used by rice farmers in other Asian countries. The use of green manures in rainfed lowland rice is, however, extremely limited (Garrity and Flinn, 1988). Between 1974 and 1990 there was a sharp decrease in the use of green manures in China and in other countries its usage seems to have become incidental. Reasons for this decline are the increased availability of relatively cheap mineral fertilizers, labour constraints in the incorporation of bulky amounts of green manures, no direct benefits in the form of food or cash and land constraints for small farmers (Roger, 1995). The disbanding of many agricultural communes and the reallocation of labour was of particular importance for the decline in China (Roger, 1995).

Sustainability issues together with the discovery of stem-nodulating legumes such as *Sesbania rostrata* have revived the interest in green manures in recent years (Roger, 1995). *Sesbania rostrata* is fast-growing and fixes nitrogen more actively than most root-nodulating legumes. In Senegal *Sesbania rostrata* produced a total dry matter yield of about 10 tonnes ha^{-1} (equal to about 50 tonnes fresh green matter ha^{-1}) after only 8-9 weeks of growth. This represents an accumulation of more than 200 kg N ha^{-1} and an assumed provision of about 100 kg N ha^{-1} to a rice crop (Rinaudo et al., 1988). In a field experiment in Bangladesh, *Sesbania rostrata* produced 7.4 tonnes ha^{-1} dry matter (about 37 tonnes ha^{-1} fresh green matter) in 60 days while *Sesbania sesban* produced 5.8 tonnes ha^{-1} dry matter (29 tonnes ha^{-1} fresh green matter) in the same period. The estimated addition of nitrogen to the soil was 252 kg ha^{-1} for *Sesbania rostrata* and 139 kg ha^{-1} for *Sesbania sesban* (Bhuiyan and Zaman, 1996). The incorporation of a 40-60 day old crop of *Sesbania* may increase rice yield with 1000-3000 kg ha^{-1} (Roger, 1995). This is, however, not possible with the only 5-6 tonnes ha^{-1} fresh green matter productions of *Sesbania* which were achieved in Sukumaland after 2-3 months of growth. Nair (1988) pointed to the fact that biomass production of green manures is seriously restricted by climate in semi-arid environments. He also stated that growing trees on bunds can be unattractive to farmers because these bunds are usually used as footpaths (Nair, 1988). Growing trees on bunds might further aggravate the problem of birds pests because such trees offer good landing and hiding places for birds.

During 1994/95 and 1995/96 the Kilimo/FAO Plant Nutrition Programme in Shinyanga region compared the application of 30 kg N ha^{-1} in the form of urea to rice plants at tillering with the incorporation of 10 tonnes ha^{-1} farmyard manure and 10 tonnes ha^{-1} rice husks prior to rice transplanting. The results from these on-farm activities over both seasons showed that all treatments increased the average control rice yield of 2580 kg ha^{-1} by 900-1000 kg ha^{-1} (Makoye and Winge, 1996 and personal communication with J.J. Makoye). Sufficient amounts of rice husks are only available near rice milling machines and can thus be applied only very locally. About half of the households in Sukumaland own livestock. Population growth and increased rice cultivation in the valleys have, however, decreased the available grassland area. As a result the number of livestock units per capita in Sukumaland decreased from 2.5-3.0 in 1945 to 1.0-1.2 in 1990 (Meertens et al., 1996). For Mwanza region it was estimated that 3.6 tonnes of farmyard manure is potentially available per year for each household with an average cultivated area of about 2.5 hectares (Meertens and Lupeja, 1996). This is enough to supply a dose of 10 tonnes ha^{-1} on the average 0.32 ha of cultivated rice per household in a dry season for Mwanza region (Meertens and Lupeja, 1996), while nothing remains for other cultivated crops such as maize, cotton and cassava. Livestock is kept at night near to the houses in open places. Almost no crop residues or other plant materials are added as a bedding to the livestock wastes on these places. It is therefore confusing to describe this open kraal manure as farmyard manure. Analysis of a representative sample of good quality kraal manure in Sukumaland revealed that on dry matter basis it contained 1.05% N, 0.19% P and 0.56% K (Lupeja and Meertens, 1996). The kraal manure contains, however, between 20-30% water so 10 tonnes of kraal manure contains roughly 79 kg of N, 14 kg of P and 42 kg K. The release of nitrogen from the kraal manure in the first year is less than half of the total. This explains why an application of 10 tonnes kraal manure in Sukumaland has the same effect on rice yield in the first season as an application of 30 kg N in the form of urea. However, the advantage of kraal manure is that it also supplies some nitrogen to the soil after the first year.

Ravnborg (1990) states that 70% of the households in Usagara division, a densely populated area near to Mwanza town, use kraal manure and that farmers have started to carry manure from the kraal at the homestead to fields other than the homegardens. A survey in Mwanza region showed, however, that kraal manure is only transported by few households to nearby fields of maize and cotton. Small quantities of manure are often applied to small gardens with tomatoes or other horticultural crops. Very few people transport kraal manure to the relatively distant rice fields. The main reasons for not applying kraal manure are that many households do not have (enough) livestock and that those with livestock often do not have transport means. In the absence of oxcarts and wheelbarrows the transport of bulky amounts of kraal manure to distant fields becomes too laborious (Meertens and Lupeja, 1996). Furthermore a survey in Maswa district, Shinyanga region, revealed that soil fertility in rice fields was considered adequate by one third of the farmers and this was the main reason for not using kraal manure (Meertens and Ndege, 1993).

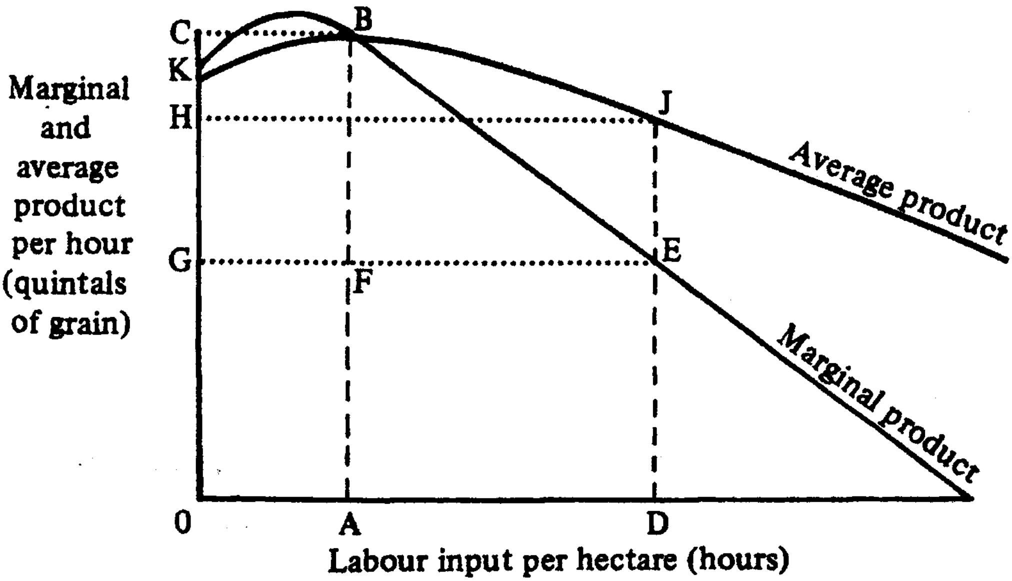
The potential of green manures for soil fertility improvement in rice fields is low in Sukumaland because the semi-arid climate and the short available period before rice transplanting strongly reduce biomass production. Applications of 10 tonnes of locally available resources such as kraal manure and rice husks increase rice yields in a similar way as an application of 30 kg N ha^{-1} in the form of urea at tillering. However, the high quantities needed confront households with availability problems, and labour problems during transporting and application, as discussed below.

Labour productivity and use of local resources for soil fertility improvement

Labour intensive methods for improving soil fertility like incorporating green manures and rice straw or application of farmyard manure are not widely adopted by rainfed lowland rice farmers. A survey in Maswa district, Shinyanga region, showed that only 2% of all households applied kraal manure to their rainfed lowland rice fields (Meertens and Ndege, 1993). In Asia this is often due to availability of relatively cheap mineral fertilizers and to labour constraints for incorporating bulky organic fertilizers (Roger, 1995). Households are not eager to increase their inputs of labour per farm and per field. Instead of incorporating rice straw it is common in Asia to use rice straw for fuel or to burn it in the field for reasons of convenience. The ashes are returned to the soil but the distribution over the field is not proper (Mutert, 1995). Deep placement of urea fertilizers is more efficient than broadcasting urea into the floodwater but this last practice is still widely followed by many Asian rice farming households (De Datta, 1995). The disadvantage of deep placement of urea fertilizers by hand is that it requires a much higher input of labour from the households in comparison to broadcasting urea into the floodwater (Ten Have, 1989; Mohanty et al., 1999).

Higher inputs of labour can be a problem for households when the requested additional amount of labour is not available at the household level. It is, however, also possible that households are able to increase their labour inputs at the farm and field level but are not willing to do so. Farmers who are not incorporated in a market economy with money prices on inputs and outputs make choices between labour and leisure on the basis of weighing the expenditure of time in relation to the returns on the work effort (Netting, 1993). An individual will only work so long as the marginal product of the extra effort, that is the increase in total product from the extra effort, is valued more highly than the foregone leisure (Upton, 1996). This changes when additional labour has to be supplied to a smaller farm size due to population growth in order to produce additional food for the growing population with no access to external inputs. Under very high population densities farmers have to give up their periods of seasonal freedom from agricultural work and acquire the habit of regular daily work during long hours all the year round (Boserup, 1965). Figure 7.1 shows, however, that high labour inputs per hectare lead to lower marginal and average products per hour of labour. The average product per hour, that is the total product divided by the

Fig. 7.1
Returns to Labour under Different Intensities of Land Use



Source: Upton (1996)

number of hours, is equivalent to the labour productivity. When labour inputs per hectare increase from OA to OD, the total product per hectare increases from area OABC to area ODJH (Figure 7.1). In case there is still some unexploited virgin land the economic optimum policy of farming households is, however, to operate an extensive system with a large land-labour ratio and thus low labour inputs and yields per hectare (Upton, 1996).

A splendid example of intensified labour use in agriculture due to population pressure and land shortage is supplied by Ukara, a small island in the southeastern part of Lake Victoria near Sukumaland. This island appears to have been already unusually densely settled for African standards from the seventeenth century onwards. In 1965 Ukara had a population density of 207 people km^{-2} (Ludwig, 1968). So the Wakara people have been confronted with population pressure and land shortage for a long time. Land shortage forced them to practise permanent farming on small farms with high inputs of labour per unit land. Before the arrival of the Europeans in the nineteenth century they had already been using for a long time farmyard manure and green manure to maintain soil fertility (Ludwig, 1968). Farmyard manure is applied to the fields prior to the planting of bulrush millet (*Pennisetum typhoides*). During the first weeding a green manure crop, mainly *Crotalaria striata*, is planted in between the bulrush millet. After the harvest of bulrush millet the green manure crop continues to grow to give a sufficient quantity, about 25 tonnes ha^{-1} (Rounce and Thornton, 1945), of fresh green matter. Later during the dry season it is incorporated in the soil at a mature stage. Additional supplies of nutrients and organic matter can come from the incorporation of tree leaves and the application of ashes, household refuse and night-soil. In addition to fertilizing the soil the Wakara also use several methods to control erosion. These include cultivation on (tie)-ridges, construction of terraces (with or without stones), filling up of gullies with stones and plants (grasses, sisal, *Euphorbia*) and the construction of large earth banks across small developing water-courses (Ludwig, 1968).

The INM methods performed by the Wakara all require substantial additions of labour. Farmyard manure is obtained from cattle (2-3 units per household), which are kept mainly inside roofed stables. The cattle are standing on pits of about one metre deep which slowly fill up with their droppings and all kind of plant material (fodder grasses, weeds, tree leaves, crop residues) collected by the farmers. This system enables each household to apply 10-12 tonnes of farmyard manure to each hectare of the entire cultivated area (average 1.7 hectares in 1965) every 2-3 years (Ludwig, 1968). The farmyard manure is transported to the fields in baskets carried on the heads. The production and application of farmyard manure, the incorporation of green manure and the erosion control methods are all labour intensive. Ludwig (1968), estimated that the Wakara needed an average 12 hours agricultural work per day to perform their intensive way of farming. He further calculated that the labour productivity on Ukara was much less than on the mainland in Kwimba district, Mwanza region, or than on the neighbouring Ukerewe island (Table 7.1). Table 7.1 shows that the lower labour productivity on Ukara is accompanied by a higher land productivity, a lower land availability per caput and a lower proportion of cash crops.

Table 7.1
Farm Management Data on Ukara, Ukerewe Islands and from Kwimba in Sukumaland

	Kwimba	Ukerewe	Ukara
Persons per Household	6.6	9.0	10.9
Total cultivated crop area (ha)	2.3	2.5	1.7
Subsistence crops (ha)	1.3	1.6	1.4
Cash crops (ha)	1.0	0.9	0.3
Available cultivated crop area per caput (ha)	0.35	0.28	0.16
Gross return total farm land (TShs ha^{-1})	188	190	504
Gross return to field work (TShs $hour^{-1}$)	0.50	0.54	0.16

Source: Ludwig (1968)

Rounce and Thornton (1945) noticed in the 1930s that in order to pay tax the Wakara had to search for work on the mainland due to insufficient fertile valleys for rice cultivation, their only cash crop. A recent visit to Ukara island by the Kilimo/FAO Plant Nutrition Programme in Mwanza region[1] showed that the production of crops is still mainly for own consumption and that only small quantities are available for selling. The necessary additional cash is mainly obtained by young people from fishing and temporary work as cart pullers (a hard, lowly-paid and unpopular job) in Mwanza town. The frequent absence of strong, young people has led to a partial collapse of erosion control methods on the island. Further changes observed were the sharp decline of bulrush millet cultivation due to increased cropping of tuber crops, in particular cassava. Farmers stated that cassava requires less labour and produces more food than bulrush millet. These changes in crops led also to a transformation of soil fertility management. Green manure crops had almost disappeared due to the long growth cycle of cassava and were replaced by an intensified use of farmyard manure. A similar process of disintensification due to labour scarcity resulting from migrant wage employment and fishing has been observed by Conelly (1994) on Rusinga island in the Kenyan part of Lake Victoria.

Around 1945 Rounce (1949) was concerned about the future of agriculture in Sukumaland. Inspired by the practices on Ukara he recommended a wide range of labour or capital intensive methods to allow sustainable agriculture in Sukumaland. Rounce's recommendations concerning soil fertility (farmyard manure, green manure, mulching, erosion control) are strikingly similar to the INM methods advocated by Smaling et al. (1996) and Pretty (1995). Fifty years later almost all recommendations by Rounce are still widely rejected by farmers in Sukumaland (Meertens et al., 1996). Population pressure and land shortage are apparently not yet serious enough in Sukumaland to induce high labour inputs per unit land with decreasing labour productivity. Even Wakara who migrated to Sukumaland did not continue their intensive way of farming, but started to grow instead crops on large farms in an extensive way without use of farmyard manure or green manure. In Sukumaland they are able to become cash-cropping, semi-permanent cultivators with a much higher return per hour of work (Ludwig, 1968), due to lower population pressures and thus less land shortages. A similar shift from intensive to extensive ways of farming has been documented by Netting et al. (1993) for the Kofyar on the Jos Plateau in Nigeria. These shifts confirm the statement of Upton (1996) that the economic optimum policy of farming households is to operate an extensive system wherever this is possible.

In the absence of capital inputs like mineral fertilizers, herbicides and mechanical implements, farm households tend to over-elaborate the use of labour intensive methods when confronted with serious land shortages. The failure to transform from this pattern was called agricultural involution by Geertz (1968) for the situation in Indonesia during the 1960s. This term was copied by Lagemann (1977) for eastern Nigeria where very high population densities had led to a decline in soil fertility, farm production and labour productivity. The current situation on the Ukara and Rusinga islands are also perfect examples of agricultural involution. Ludwig (1968), Lagemann (1977) and Conelly (1994) have shown that farmers react to agricultural involution with migration, seasonal migration for cash earning or an increase in off-farm employment without migration.

Nutrient balances for rice cropping systems in Sukumaland

The very limited use of mineral fertilizers and locally available resources in Sukumaland rice cultivation raises the question whether present farming practices are sustainable in terms of nutrients. Estimations of the inputs and outputs of nutrients in a certain cropping system, farming system or land use system form the basis of so called nutrient balances. The outcome of such estimations can assist researchers in cooperation with farmers in the selection of appropriate INM technologies.

Stoorvogel and Smaling (1990) calculated major nutrients balances for different land use systems and crops in 38 sub-Saharan African countries. These calculations included major nutrient flows for upland rice, naturally flooded rice and irrigated rice in Tanzania. Naturally flooded rice occupies in their calculations 85% of the total rice cultivated area in Tanzania. The nutrient balances for N, P and K were all zero for the naturally flooded rice cropping systems due to inputs from biological N fixation and sedimentation. A considerable part of what Stoorvogel and Smaling characterize as naturally flooded rice cropping systems are in fact bunded rainfed lowland rice cropping systems. Kanyeka et al. (1994) estimate that 32% of all cultivated rice in Tanzania is bunded rainfed lowland rice. Almost all rice in Sukumaland is bunded rainfed lowland rice (see Chapter 4). A nutrient balance for the rice cropping system in northern Sukumaland provided by Budelman et al. (1996) indicated that nutrient balances for N, P and K were not zero but negative (Table 7.2).

Table 7.2
Two Scenarios for Average Annual Major Nutrient Balances (kg ha^{-1}) for the Rainfed Lowland Rice Cropping System in Sukumaland, Tanzania

		Scenario A[a]			Scenario B[b]		
		N	P	K	N	P	K
In 1:	Mineral Fertilizers	ns	ns	0	ns	ns	0
In 2:	Organic Fertilizers	ns	ns	ns	?	?	?
In 3:	Wet and Dry Deposition[c]	8.0	1.0	3.0	8.0	1.0	3.0
In 4:	Biological N Fixation	2.1			8.7		
In 5a:	Floodwater	?	?	?	2.0	0	6.0
In 5b:	Sediments	?	?	?	0.8	0.4	6.0
Total Inputs		*10.1*	*1.0*	*3.0*	*19.5*	*1.4*	*15.0*
Out 1:	Crop Products	22.5	3.9	7.8	17.8	3.1	6.0
Out 2:	Crop Residues	24.5	4.3	75.0	12.1	2.1	36.9
Out 3:	Leaching	15.0	ns	ns	ns	ns	ns
Out 4:	Denitrification	4.1			4.0		
Out 5:	Erosion	ns	ns	ns	ns	ns	ns
Total Outputs		*66.1*	*8.2*	*82.8*	*33.9*	*5.2*	*42.9*
Balance		**-56.0**	**-7.2**	**-79.8**	**-14.4**	**-3.8**	**-27.9**

a *Source:* Budelman et al. (1996)
b *Source:* Chapter 4 of this thesis, Greenland (1997)
c *Source:* Bootsma and Hecky (1993) for N and P and Smaling and Fresco (1993) for K
ns not significant

An important feature of rice cultivation in Sukumaland is that farmers fail to plant rice in some years due to unreliable, low rainfall. Budelman et al. (1996) acknowledged this aspect in their balance sheet with the estimation of five successful rice years out of a total of eight years. This is almost equal to the estimation of six successful rice years out of a total of nine years (see Chapter 4). However, the nutrient balance calculated by Budelman et al. still needs further corrections to reach more realistic figures, as explained below.

Stoorvogel and Smaling (1990) distinguished mineral fertilizers, organic manure, wet and dry deposition, biological nitrogen fixation, and sedimentation as nutrient inputs; and removal of crop products and crop residues, leaching, denitrification, and erosion as nutrient outputs. These inputs and outputs were subsequently included in a nutrient balance bookkeeping system named NUTMON (Smaling and Fresco, 1993). Table 7.2 presents annual nutrient balances for N, P and K ha^{-1} for the rainfed lowland rice cropping system in Sukumaland on the basis of Budelman et al. (1996) with and without corrections.

Budelman et al. (1996) state that there are currently no significant inputs of mineral fertilizers and kraal manure in Sukumaland rice cultivation (Table 7.2). No application of kraal manure does, however, not mean that there are no inputs of organic matter in the rice fields. The lower situated rice fields receive most of their water through runoff from the higher parts of the slopes. After heavy rainfall, streams of water flow rapidly downwards and take with them all kind of organic matter from the homesteads, kraals and upper fields. Some few farmers deliberately dig canals to lead water, which has passed the homestead and kraal, into their rice fields (Meertens and Ndege, 1993). Unfortunately there are no data available for this type of input, but the existence of this input should nevertheless be noted.

Budelman et al. (1996) restrict biological nitrogen fixation to free-living bacteria only. However, according to Greenland (1997) blue-green algae seem to almost always be present in flooded rice fields. Together with free-living bacteria these organisms contribute an average of 13 kg N ha^{-1} yr^{-1} to the rice crop in rainfed lowland rice cropping systems (Greenland, 1997). Such contributions only occur under flooded conditions in the presence of a rice crop. With six successful rice years out of a total of nine years in Sukumaland the annual contribution is then about 8.7 kg N ha^{-1} (Table 7.2), and not just 2.1 kg N ha^{-1}.

For lowland rice cropping systems sedimentation covers inputs of nutrients dissolved in floodwater and from sediments (Greenland, 1997). Budelman et al. (1996) mentioned that nutrients in runoff water may matter but that no data were available. The only recent data found for rainfed lowland rice are contributions of 2 kg N, 0 kg P and 6 kg K ha^{-1} yr^{-1} from 250 mm floodwater (Greenland, 1997). It is assumed that 250 mm floodwater fits the Sukumaland case. Sediments deposited by runoff water may contribute considerable amounts of potassium (Grist, 1975). A low deposition rate of 0.1 mm yr^{-1} and the lowest nutrient concentrations in tropical soils in Asia give contributions of 0.8 N, 0.4 P and 6.0 K ha^{-1} yr^{-1} (Greenland, 1997). These values are regarded as the best estimations available for the rainfed lowland rice cropping system in Sukumaland (Table 7.2).

The values for nutrient contents of rice grain (1.16% N, 0.20 % P, 0.39% K) and rice straw (0.62% N, 0.11% P, 1.89% K) used by Budelman et al. (1996) are average in comparison to figures mentioned by Grist (1975), Pieri (1992), Ahn (1993) and Greenland (1997). These medium levels are regarded as appropriate for the short-maturing, tall *indica* rice cultivars, which are mainly used in Sukumaland. Also the harvest index (weight ratio of grain to total aboveground dry matter) of 0.44 from van Duivenbooden (1992) is regarded appropriate for these types of cultivars. The calculations of nutrient outputs from removal of rice grain and rice crop residues by Budelman et al. (1996) are based on an average rice yield of 3100 kg grain ha^{-1} and 3950 kg straw ha^{-1}. In Chapter 4 it was mentioned, however, that the average rice yield in Sukumaland is only 2300 kg grain ha^{-1}. The production of rice straw is in that case 2930 kg ha^{-1}. It is not explained in Budelman et al. (1996) why there is no correction for failure to grow rice in relation to the removal of rice straw. Scenario B uses the correction factor of 0.67 (six harvests in nine years) for both crop products and crop residues (Table 7.2).

Most rice in Sukumaland is grown on sandy clayloams with a kind of hardpan within 50 cm from the surface. In such lowland rice fields the leaching of nitrogen is not a problem (De Datta, 1995). Greenland (1997) used therefore zero levels for leaching of nutrients in rainfed lowland rice cropping systems. Scenario B (Table 7.2) adopts these figures from Greenland. Leaching of nitrogen is, however, present on the much less common, more sandy, elevated rice fields. In northern Sukumaland there are relatively more sandy, elevated rice fields but it is incorrect to use these in scenario A as the standard type of rice fields for calculating leaching losses (Table 7.2).

Both scenarios of nutrient flows in rainfed lowland rice fields in Sukumaland give negative balances for the major nutrients N, P and K but the magnitudes of the negative figures are substantially different (Table 7.2). Scenario A leads to considerably higher negative balances of K, N and P. Budelman et al. (1996) argue on the basis of scenario A that the removal of rice straw due to grazing by livestock and use as thatching material leads to a highly unsustainable situation. According to Budelman (1996) material for roofing should be removed from the field immediately after the harvest and the remaining straw carefully burned, and ashes spread and superficially worked into the soil. Budelman (1996) sees this as a first correction to the recommendation of applying urea. Furthermore, Kajiru (1995) states that the recommendation to use 30 kg N ha^{-1} in the form of urea only aggravates the negative nutrient balance for other nutrients than N due to yield increases in rice grain and straw. Incorporation of rice straw (at least 50%) and application of cattle manure from improved kraal manure management would reduce nutrient deficits in the rice soils (Kajiru, 1995). A further step is to investigate the possibility of using a compound fertilizer whereby the addition of phosphorus is regarded as essential (Budelman, 1996).

Even if scenario A was right, the proposed corrections to the recommendation of applying urea on the basis of the major nutrients balances from scenario A all require higher investments of labour and/or cash from the rice farming households. Compound fertilizers are more expensive than single nutrient fertilizers. Incorporation of rice straw and application of kraal manure need substantial higher labour investments. The high C/N ratio of rice straw leads to a temporary nitrogen shortage immediately after incorporation. To offset this temporary nitrogen shortage farmers need to add a dressing of nitrogenous fertilizer (Ahn, 1993). An example from Sri Lanka shows that 20 kg urea ha^{-1} is needed for this (Mulleriyawa and Wettasinha, 1997). In The Netherlands it is advised to add 7 kg N for each ton of incorporated straw (Ministerie van Landbouw en Visserij, 1980). Incorporation of rice straw for reduction of nutrient deficits in the rice soils competes with the use of rice straw as thatching material and as cattle feed. In the past households used grasses like *Hyparrhenia spp.* as thatching material but the pressure from livestock grazing and rice cultivation on former grasslands has practically removed this option.

Crop residues in the field like rice straw are important additional livestock feeding due to insufficient grazing areas in Sukumaland. For Mwanza region it is estimated that only about 0.5 ha grassland is available for one livestock unit (Meertens and Lupeja, 1996). This is far below the recommended 4 ha grassland for one livestock unit (Gijsman and Rusamsi, 1991). In northern China as well the use of rice straw as fodder makes the incorporation of rice straw less attractive for farmers (Yang and Janssen, 1997).

So why should rice farming households use more labour, cash, and rice straw for sustainable rice cultivation in Sukumaland? They might do this when there are deficiencies of nutrients in the rice soils which already seriously affect the level of rice yields. Chemical analysis of typical, hardpan rice soils in Sukumaland (see Chapter 5) revealed that they have a very low amount of total nitrogen (0.7-0.9 g kg^{-1}), a low amount of available phosphorus (3.0-6.0 mg kg^{-1} P-Bray), and a medium amount (0.25-0.37 meq $100g^{-1}$) of exchangeable potassium. These results are confirmed by good responses of rice to low applications of nitrogen (30 kg ha^{-1}) in the form of urea, and less clear responses to phosphorus applications (see Chapter 5). The absence of a response of rice to an application of 2.5 tonnes ha^{-1} rice husks ash (equivalent to 162 kg ha^{-1} K, 74 kg ha^{-1} P and only 3 kg ha^{-1} N) in an on-farm experiment in Magu district, Mwanza region (Bagarama et al., 1995), can serve as a further confirmation of the above mentioned conclusions. When there are no serious deficiencies of K and P in the rice soils there seems to be as yet no justification for recommending compound fertilizers and incorporation of rice straw. Grist (1975) argued that the inclusion of potassium in mineral fertilizers should not be based on an insurance or balancing principle unless it is demonstrated that there is a deficit. Potassium deficits, which one would expect from the nutrient balance according to scenario A in Table 7.2, have not yet been demonstrated in the rice soils of Sukumaland.

Nutrient balances versus nutrient stores

Is the nutrient balance from scenario B a better reflection of the reality? This balance sheet gives negative balances of 14.4 kg ha^{-1} yr^{-1} for N, 3.8 kg ha^{-1} yr^{-1} for P and 27.9 kg ha^{-1} yr^{-1} for K (Table 7.2). These amounts of nutrients have to be supplied by the soil annually to make reasonable harvests possible. Soil organic matter is the main supplier of nitrogen and phosphorus in the soil. Soil samples have shown that there is about 1% of organic matter in hardpan rice soils, with a C/N ratio of 14 (see Chapter 5). Generally, only the N in the plough layer (to 15-20 cm depth) is considered in evaluating N availability (Kundu and Ladha, 1999). Assuming an annual mineralisation rate of 3%, soil organic matter containing 60% carbon, and a weight of the plough layer of 2 million kg ha^{-1} there will be a release of about 26 kg N ha^{-1} yr^{-1} of which about 14 kg will be recovered by plants (Ahn, 1993). Partial replenishment of organic matter takes each year place through turning under rice stubbles and weeds (Grist, 1975), droppings from cattle grazing the rice straw (Greenland, 1997), and from organic matter brought by runoff (Table 7.2).

Besides nitrogen the soil organic matter will also release about 2.6 kg P ha^{-1} yr^{-1}. Additional phosphorus is obtained from inorganic compounds in the soil. An important aspect of flooding is that it brings the soil pH near to neutral, which makes most nutrients, particularly phosphorus, more available. In most soils this increase in soil solution phosphorus is adequate for rice growth. The results from normal soil tests are not applicable because they do not measure the release of phosphorus when the soil is flooded (Ahn, 1993).

An average 3 meq exchangeable K kg^{-1} in Sukumaland rice soils (see Chapter 5) gives an estimated 234 kg ha^{-1} of exchangeable K for the zone up to 20 cm on the assumption of a soil weight of 2 million kg ha^{-1} and a soil moisture content of 30%. This amount of exchangeable K in the soil is according to the nutrient balance of scenario B enough for about 8 years of rice cultivation. Each year there is, however, replenishment of exchangeable K from weathering of clay minerals.

So generally rice yield levels of 2.3 tonnes ha^{-1} in six out of nine years can be sustained with the supply of N, P and K from rice soils when we follow the nutrient balance of scenario B (Table 7.2). Geertz (1968) stated that the most striking feature of lowland rice in Indonesia is its ability to produce year after year a virtually undiminished yield. Under favourable circumstances like in Indonesia (volcanic ashes) it is possible to obtain consistent rice yields of up to 3 tonnes ha^{-1} without application of nitrogen fertilizers (De Datta, 1995). In Sukumaland higher rice yields due to application of nitrogen fertilizers would alter the balance of nutrients and lower the amount of organic matter in the rice soils. This is, however, not yet the case due to non-adoption of urea by rice farming households so far (see Chapter 6). It remains questionnable if the recommended low dose of 30 kg N ha^{-1}, which gives an average rice yield increase of about 700 kg ha^{-1} (see Chapter 5), will in the short term necessitate additional applications of P and K. In south and southeast Asian countries with national average rice yields of 2-3 tonnes ha^{-1} only N fertilizers are generally recommended. In Korea, Japan, and China, balanced fertilizer use (NPK and sometimes Si) is emphasized when rice yields are between 4.5 and 7.0 tonnes ha^{-1} only (De Datta, 1995).

Discussion and conclusions

Integrated nutrient management is characterized by efficient use of a combination of locally available resources, mineral fertilizers, and methods that prevent the loss of nutrients from the system. Pretty (1995) states that farm households can reach INM through learning. The principal barrier to INM, according to Pretty, is the absence of a favourable policy environment. Halfway the 1990s there was a favourable policy environment for INM in Tanzania due to IMF/World Bank policy reforms which had reduced the access to mineral fertilizers. Adoption of INM by farm households can, however, not be guaranteed on the basis of learning only. This paper has shown that there can be serious blocks to the use of locally available resources for soil fertility improvement. Incorporation of crop residues, green manures and application/transport of farmyard manure require substantial additional inputs of farm household labour. These higher levels of labour inputs per unit of land cause a decrease in the productivity of labour. The economic optimum policy of farming households with little access to external inputs is, however, to operate an extensive system with a large land-labour ratio and thus low labour inputs and yields per hectare wherever this is possible (Upton, 1996). Only serious land shortages due to high population densities will force farm households to accept a decrease in the productivity of labour (Boserup, 1965). This explains why farm households, who are familiar with INM and actually practised it, return to extensive types of farming when the pressures of population density and land shortage are removed e.g. through migration (Netting, 1993; Ludwig, 1968). When mineral fertilizers are not available or too expensive, soil fertility has to be maintained by the use of locally available resources only. The ever higher inputs of labour needed for this maintenance of soil fertility will eventually lead to agricultural involution and not agricultural development (Geertz, 1968). According to Low (1993), a shift to LEISA translates into High-Cost, Unsustainable Livelihoods for many farm households. Given the non-adoption of urea use in Sukumaland rice cultivation, due to availability problems and gigantic price increases of urea (see Chapter 6), a similar fate is awaiting the rainfed rice farmers in Sukumaland.

Apart from labour problems, there are further constraints to the use of locally available resources for soil fertility maintenance. In semi-arid environments like Sukumaland biomass production of green manures and multi-purpose trees are seriously restricted by climate. Using green manures as an improved fallow in the rice cultivation of Sukumaland will have limited impact on the soil fertility situation due to insufficient biomass production in the three months before rice transplanting available. An experiment involving hedgerow intercropping with *Leucaena leucocephala* in maize in a semi-arid environment in Kenya concluded it was not an appropriate way to increase maize yield (Mathuva et al., 1998).

Low biomass production of grasslands in Sukumaland decreases the production of cattle manure. Cattle manure is only collected during nights in open kraals with almost no use of beddings. This further reduces the availability and quality of the cattle manure. In fact there is just enough cattle manure in Sukumaland for maintaining soil fertility in the rice fields during a bad season for rice, while nothing remains for the other fields of the households. An additional problem is that half of the households in Sukumaland do not own livestock and therefore have no easy access to cattle manure.

Shapiro and Sanders (1998) mention that most crop residues in semi-arid West Africa are removed for uses with higher economic value (feed, fuel, building materials) than soil fertility improvement. On the basis of this and the limited availability of manure they argue that moderate use of inorganic fertilizers is required for increasing yields in a sustainable way (Shapiro and Sanders, 1998). Similar statements have been made by Mwangi (1997) and Larson and Frisvold (1996) for entire sub-Saharan Africa. Structural adjustment programmes in sub-Saharan Africa have, however, currently deteriorated the accessability of mineral fertilizers for most farm households due to removal of government subsidies. The consumption and demand of mineral fertilizers in Tanzania declined significantly in recent years (FAO, 1997). In West Africa too the use of mineral fertilizers declined or stagnated in the 1990s (Reardon et al., 1997; Koning et al., 1997). A detailed description of soil fertility management practices by smallholder farmers in Zimbabwe (Campbell et al., 1998), showed that farmers used a combination of organic and inorganic fertilizers around 1991 but that recent sharp increases in fertilizer prices are a threat to the sustainability of this system.

This paper shows that the prospects for INM in Sukumaland rice cultivation are not positive due to labour and cash constraints at the farm household level and due to the semi-arid nature of the environment. Pretty (1995) presents some examples of successful sustainable agriculture developments from all over the world but fails to supply information about the ecological, economic, demographic and public policy conditions, which enabled these successes. Adoption of INM is influenced by socio-economic conditions at macro- and micro-level, so for each case one needs to know the existing socio-economic boundaries at each system level (Smaling et al., 1996). This requires a good understanding of the circumstances and motives of farm-household managers, natural resources and the farming communities (Low, 1993). This paper indicates that the land-labour ratio of a certain farming system is of particular importance with regard to adoption of INM methods based on locally available resources. In addition, one needs information about ecological circumstances (soils, rainfall), degree of market incorporation, off-farm employment opportunities, ownership of livestock, population density levels and public policies to evaluate the profitability or other aspects of various INM methods.

Calculations of nutrient balances at field, farm or land use level assist in detecting the specific problems of soil fertility management and in supplying some suggestions for sustainable farming systems. However, calculations of nutrient balances are based on a number of assumptions which can be interpreted in different ways. This paper shows that this can lead to different scenarios for nutrient balance calculations of Sukumaland rice cultivation and as a result to different suggestions for soil fertility management. It is therefore better to combine the interpretation of nutrient balance calculations with farmers' knowledge, perceptions and opinions on soil fertility management. A good example of such a combination is the use of resource flow models made by farmers in the south of Mali (Defoer et al., 1998). Farmer participatory rural appraisals on integrated soil fertility management with much less quantification of nutrient flows give, however, equally good rankings of soil fertility management practices at a much lower cost and within a shorter period (Kileo et al., 1996). Deugd et al. (1998) point further to the crucial learning dimension of farmer participatory methods related to INM.

The nutrient balance for an average rainfed, lowland rice field in Sukumaland, presented in this paper as scenario B, suggests that there might be not yet a serious soil fertility problem in such a rice field. This can explain why farmers in some parts of Sukumaland state that their rice fields are still fertile. It can further explain why farmers are not interested at all to transport kraal manure to distant rice fields and are very reluctant to adopt the use of urea in rice. It appears that at present there is no sufficiently pressing need for INM in Sukumaland rice cultivation. From a farming systems perspective it would be more interesting to investigate the possibilities for INM in other sections of the farming systems. Cassava, maize, cotton and sweet potatoes are in fact also important food or cash crops in Mwanza region (Meertens and Lupeja, 1996). They are mainly grown on the upper sections of slopes, which are characterized by infertile sandy soils with relatively high nutrient losses due to leaching and erosion. Recent surveys in Sukumaland have shown that farmers are indeed first experimenting with INM in maize (with or without cassava), cotton and horticultural crops on the sandy soils (Ravnborg, 1990; Meertens and Lupeja, 1996). The Sukumaland rice cultivation case shows that negative nutrient balances do not always require immediate actions in the form of INM. Negative nutrient balances and soil mining practices in the south of Mali were still regarded as more efficient than considered alternatives in a farm household modelling approach (Bade et al., 1997). The adoption of INM thus is a complex issue which can not depend on the calculations of nutrient balances alone but needs active participation of farmers and additional information on ecology, economy, public policy, land-labour ratios of the farming systems and farm household strategies. In Sukumaland the introduction of INM in rainfed, lowland rice cultivation may not be urgent yet, especially in the predominant rice fields on hardpan soils.

Notes

1 Personal observation

Acknowledgements

Extension workers on Ukara island, in particular Joseph Kapunda, are thanked for their assistance during the two-day field trip of the Kilimo/FAO Plant Nutrition Programme in May 1995 on Ukara. Joseph Makoye, the cash crop subject matter specialist in Shinyanga region, is thanked for supplying recent results from rice on-farm activities in Shinyanga region. Joost Brouwer, Bert Janssen and Niels Röling are thanked for their comments on an earlier draft.

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8. The Potential of INM/LEISA for developing Sustainable Agriculture under the current circumstances of SSA

In this chapter the Sukumaland case study is compared with some selected case studies from SSA and Asia to see the important resemblances and differences in soil fertility management practices. The chapter starts with an overview of soil fertility management practices in farming systems with varying land use intensities, and by an investigation of determinants which can trigger shifts in soil fertility management practices. The productivity of labour in farming systems with varying soil fertility management practices is elaborated on. The chapter ends with a discussion and some conclusions concerning the **research problem of this thesis:** *the potential of INM/LEISA in developing sustainable agriculture in SSA in the context of liberalized international agricultural trade, structural adjustment programmes, and strong population growth.*

Soil fertility management in relation to land use intensity

Farming differs all over the world and there are many ways of classifying farming systems into different groups. One important classification is to group farming systems according to their intensity of land use. The intensity of land use is then defined by the number of years of cultivation in relation to the number of years that the land remains fallow. A common used quantification of land use intensity is the *R*-factor. The *R*-value is calculated in the following way by Ruthenberg (1980): (number of crop cycles per year x number of years of cultivation x 100) divided by (number of years of cultivation + number of years of fallow). The *R*-factor can have values between 0 and 300. Boserup (1965) was among the first people to describe and group farming systems according to their intensity of land use. She classified farming systems into the following five intensities of land use:

forest fallow	
(one or two years cultivation and twenty to twenty-five years fallow)	*R*= 0-10
bush fallow	
(two or more years cultivation and eight to ten years fallow)	*R*= 10-40
short fallow	
(one or two years cultivation and one or two years fallow)	*R*= 40-80
annual cropping	
(fallow only in the months between harvest and next planting)	*R*= 80-100
multi-cropping	
(two or more successive crops on the same field each year)	*R*= 200-300

Farming systems with *R*-values between 100 and 200 are intermediary stages between annual cropping and multi-cropping. Some farming systems combine in different parts of the farm land use intensities from two or more of these five groups. Good examples are the changes in intensity of land use for fields with varying distance to the houses in West Africa (Gleave and White, 1969), which are described in more detail by Lagemann (1977) for eastern Nigeria and Prudencio (1993) for Burkina Faso.

Soil fertility management practices almost always change when progressing from forest fallow systems to multi-cropping systems. Boserup (1965) states that there is a close association between the systems of fallow and the techniques for fertilization. In forest fallow systems, soil fertility is maintained through the regenerating effect of the long fallow period. When farmers decide to use a part of the forest for cultivation they simply burn the vegetation and obtain fertile fields from the ashes. After two years of cultivation the fertility of the fields has declined and farmers shift to another part of the forest. After twenty to twenty-five years the original plot has reclaimed its natural vegetation and can be used again by the farmers for cultivation. In bush fallow systems the reduced fallow period produces less biomass and thus less ashes after burning. Additional fertilization may be provided by cutting branches from surrounding trees and applying these to the plots prior to burning. This is known as the 'chitimene' technique (Pingali et al., 1987). In short fallow systems, the fallow period has become so short that grasses dominate the fallow vegetation. The disadvantage of grasses is that fire can not eliminate the roots of grasses in the soil. The intensive use of a hoe is now needed for the preparation of the land. The burning of grasses supplies insufficient amounts of nutrients to the soil. Additions of nutrients in the form of organic wastes from the household and dung from domesticated animals, who can feed on the grasses of fallow land, are often needed in the short fallow systems. In systems with almost no fallow land, such as annual cropping and multi-cropping, it becomes necessary to maintain soil fertility through more labour-intensive fertilizing techniques such as manuring and composting and/or the purchase of mineral fertilizers. The only exceptions are found in areas where the soils are very fertile due to their volcanic origin. On the Adja plateau in Benin the oil palm fallow is a less labour-intensive fertilizing technique through the decomposition of trunks, roots and other biomass left in the field (Brouwers, 1993). Information on soil fertility management practices from more than fifty locations in ten countries of SSA confirm that organic fertilization techniques are closely related to the intensity of land use. This is presented in Figure 8.1, where manure is a more labour-intensive and higher quality type of animal waste use than kraal dust.

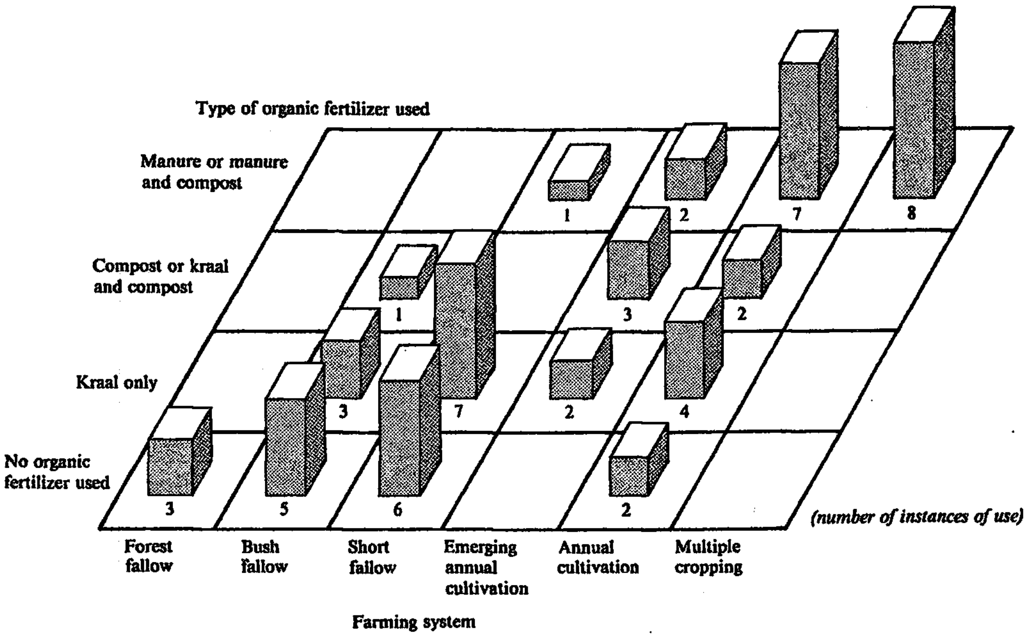
Factors inducing transitions in soil fertility management practices

The intensity of land use increases when fallow becomes less frequent and thus the cultivation frequency increases. There are several factors which can cause an increase in the intensity of land use, and therefore a transition in the maintenance of soil fertility. One important factor is population density. The following section starts with this factor and then discusses other factors which can induce transitions in soil fertility management practices, such as integration in markets, land laws and land rights.

Population density

Boserup (1965) was the first author who strongly argued that an increase in population density would induce a transition in land use intensity and thus soil fertility management. When in a certain forest area more people are engaged in cultivation the fallow period will diminish and the system will evolve towards bush

Figure 8.1
Fertilization techniques in relation to intensity of land use



Source: Pingali et al. (1987)

fallow and eventually short fallow. If the population continues to grow it will reach a point where all land is used for cultivation and no fallow exists anymore. According to Boserup (1965) these transitions in land use intensity only occur at certain critical levels of population density. In later publications Boserup (1981) and many others (e.g. Pingali et al., 1987; Turner et al., 1993) demonstrated with case studies from all over the world that there is indeed a strong correlation between population density and land use intensity.

In Boserup's view, population density is the dominant factor inducing agricultural change. Therefore it is unrealistic to regard agricultural cultivation systems primarily as adaptations to different natural conditions. Moreover, changes in agricultural technology are likely to result from population changes. Population growth itself is taken as given. Pingali et al. (1987), however, have shown that the concentration of population in a certain area can be caused by ecological, political as well as economic factors. High altitudes, for example, have been preferred for human settlement in tropical areas due to the better climate and lower incidence of diseases like malaria and sleeping sickness (*Trypanosomiasis*). In certain areas with lower altitude fertile soils, ample rainfall and/or absence of tsetse flies can also attract people. The concentration of people in highlands or on islands to which access was difficult has also been a means of avoiding intertribal warfare or slave trade. Lower costs for the transport of agricultural products explain the concentration of people near urban centers, railway lines, roads and rivers. Grigg (1979) pointed to the fact that ecological circumstances can restrict an increase in the intensity of land use. Multi-cropping, for example, is limited to areas with long growing seasons and sufficient available water from ample rainfall and/or the possibility of irrigation. Pingali et al. (1987) argued that permanent cultivation of field crops in humid lowlands is hard to sustain due to intensive leaching and soil acidification. Ruthenberg (1980) acknowledged these ecological differences and described different development pathways for tropical farming systems in humid, semi-humid, semi-arid and high altitude areas.

Integration in markets

The theory of Boserup predominantly relates agricultural production to household needs and wants under conditions of subsistence (Kates et al., 1993). Her theory is mainly based on examples from Africa and northern India in the 1950s, China in the 1920s, and some tribal communities in southeast Asia (Grigg, 1979). The theory is thus confined to pre-industrial societies in pre-Green Revolution times. However, in addition to the subsistence demands from a growing rural population there are also demands related to local or international markets. Descriptions of cash cropping in West Africa by Gleave and White (1969) showed that in pre-industrial societies prior to the Green Revolution there were already considerable demands from markets on agricultural production. Growing land requirements for cash cropping is according to Gleave and White a similar stimulus as population pressure for advancing from one phase of land use intensity to another. When farmers are able to sell a surplus of food crops or are able to grow cash crops in addition to food crops they want to grow more on extended farm sizes. So farming becomes more intensive in a way similar to the effect of a growing population (Binswanger and Pingali, 1988).

Market access induces the concentration of people, but high population density on the other hand encourages the development of a marketing infrastructure (Kates et al., 1993). The size of the demands related to markets depends on the distance, size, efficiency and profitability of these markets. High demands come from large urban centers and farmers living close to these centers react to these high demands by intensifying their crop and livestock production. Von Thünen (1783-1850) noticed for Europe that the intensity of farming depended on the distance to the market. Perishable dairy products and garden vegetables are produced by very intensive means in areas closest to the city (Netting, 1993). The more than 50 case studies in SSA selected by Pingali et al. (1987) also showed a clear correlation between intensity of land use and market access. Parts of SSA with good market access had predominantly annual cropping and multi-cropping systems, rather than fallow systems.

Markets are not only centers for agricultural products but also for agricultural inputs. When rural societies become more integrated into markets due to a commercialization of the agriculture, they possess more cash in addition to land and labour. If supplies are available, cash can be used to purchase agricultural inputs such as mineral fertilizers, hybrid seeds, biocides, ploughs, pumps and tractors. Hayami and Ruttan (1971) argued that the choice of the type of agricultural input depends on the relative scarcity of land and labour in a certain area. When land is abundant farmers will purchase labour saving inputs like ploughs and tractors to substitute land and capital for labour. When land is scarce farmers will buy land saving inputs like mineral fertilizers, hybrid seeds and biocides, in addition to adopting labour-intensive husbandry practices to substitute labour and capital for land. However, all types of agricultural inputs cause an intensification of land use. The use of ploughs and tractors extends the size of farms and thus reduces the fallow area in relation to the cultivated area. The use of mineral fertilizers and pumps for irrigation enables a shift from annual cropping to multi-cropping.

In contrast to the rather autonomous agricultural development pathways described by Boserup and Hayami/Ruttan, Lele and Stone (1989) stress the importance of adequate public policy measures in the process of intensification. They doubt if autonomous intensification with its demand-led growth and exclusive dependence on the market for achieving rapid growth in productivity is valid for Africa with its unprecedented population growth rates, fragile soils and declining rainfall. Under such circumstances an increased role of the state has to extend the Boserup hypothesis to a process of policy-led intensification (Lele and Stone, 1989).

Land laws and land rights

Pingali et al. (1987) mentioned that policies restricting the acquisition of new agricultural land lead to an intensification of land use. Examples are the alienation of large tracts of land to European farmers during colonial times in East Africa. Population building up in the remaining areas caused pressure on the land and hastened the development of permanent cultivation. Today this process is still continuing in the communal areas of Zimbabwe and South Africa, where small farming households have no access to the large tracts of land owned by commercial white farmers. Unequal distribution of land among farmers is, however, more widespread and pronounced in Latin America and Asia than in SSA.

Grigg (1979) stated that in many peasant societies changes in the extraction of agricultural surplus by landlord, church or state can cause an intensification of land use quite independently of population growth. The externally imposed tribute, rent, corvée labour, and taxation demand intensification by means of labour (Netting, 1993). Most examples of such forced intensification of land use come from Europe before the twentieth century and from Asia.

Productivity of labour during the transitions

An intrigueing aspect of the Boserup theory concerns the productivity of labour during the process of land use intensification. According to Boserup (1965) it is more likely that the productivity of labour declines than increases when population growth reduces the fallow period. In forest fallow systems only very little labour is required for planting and weeding while the ashes provide good crop yields for at least two years. In land use systems without fallow farmers have to use higher amounts of labour for land preparation, weeding and soil fertility management while crop yields increase rather less. The decline in labour productivity is compensated by working more hours per day, which stabilizes the productivity per labourer (Salehi-Isfahani, 1987). Even if they have the required knowledge and tools for more intensive methods of land use, farmers do not prefer intensive systems of land use due to the hard labour involved without improvement in labour productivity. According to Boserup (1965), farmers only shift to intensive systems of land use when a certain critical level of population density has been reached and they have to accept an increase in working hours and a decline in labour productivity. Boserup (1965) mentions that there are many examples of farmers who had been using intensive methods of land use and stopped these practices after migrating to less densely populated areas. One example is the disintensification in agricultural methods of European colonists from Germany and Italy when they migrated to Brazil. Examples of relapses into more extensive systems of land use in SSA are described by Ludwig (1968) for the Wakara in Tanzania, by Netting (1993) for the Kofyar in Nigeria, and by Campbell and Riddell (1984) in the Mandara mountains in Cameroon. Pingali et al. (1987) noted that societies in East Africa spread out of their concentrated settlements, abandoned the intensive practices and reverted to shifting cultivation whenever the threat of intertribal strife or slave trade ended. However, according to Boserup (1965) a sustained growth of population and of total output in a particular area leads to harder work habits and divisions of labour, which can first raise labour productivity outside agriculture and eventually also within agriculture when the necessary agricultural investments are undertaken.

The theory of Boserup was heavily criticised because of its assumption of declining labour productivities in the process of land use intensification. Grigg (1979) compiled some of these criticisms and stated that this law of diminishing returns to labour only holds when labour inputs are increased without parallel changes in capital, technology or social organization. Robinson and Schutjer (1984) argued that, on a given amount of land, labour productivity does not necessarily need to fall as output rises, thanks to technological shifts triggered by population growth. Upton (1996) confirms this by stating that the marginal product per person (which equals the increase in total product for each additional day of labour) is likely to fall when labour input rises, unless new, more-productive systems of farming can be found. Case studies from Africa showed that labour productivity in annual cropping became higher than long fallow systems once modern inputs were used (Grigg, 1979). Freeman and Smith (1996) calculated with a linear programming model that labour productivity is likely to increase in the West African Northern Guinea Savanna when farmers start to use improved maize varieties at either high or low rates of mineral fertilizers. Summarizing, it seems that an improvement in labour productivity originates from shifts to more capital-intensive technologies rather than shifts to more labour-intensive technologies.

In a later publication Boserup (1981) investigated the labour productivity in countries with variations in population density and technology levels. Table 8.1 presents the results of these investigations, which were based on data computed by Hayami and Ruttan (1971). Boserup commented that differences in output per worker are relatively small between density groups and that output per worker tends to be lower in densely populated countries for each technology level. She, however, did not mention that there is a strong increase in output per worker with higher technology levels for each density group (Table 8.1). Bairoch (1997) calculated that the agricultural labour productivity of developed countries around 1990 was 37 times higher than in the developing countries. Increased use of capital in the form of mineral fertilizers, biocides and machinery in the agricultural sectors of developed countries are apparently able to increase the labour productivity for countries with varying population densities.

Table 8.1
Average output per male, adult worker (in wheat units) according to population density and technology level around 1965

		Technology Group[a]								
Density Group	Persons/km²	I	II		III		IV		V	
1-3	0 - 4								120	(2)
4-5	4 - 16				11	(1)	19	(4)	102	(2)
6-7	16 - 64				9	(2)	9	(3)	58	(4)
8-9	64 - 256		2	(1)	5	(2)	20	(3)	39	(8)
≥10	≥ 256				5	(1)	8	(1)	46	(3)

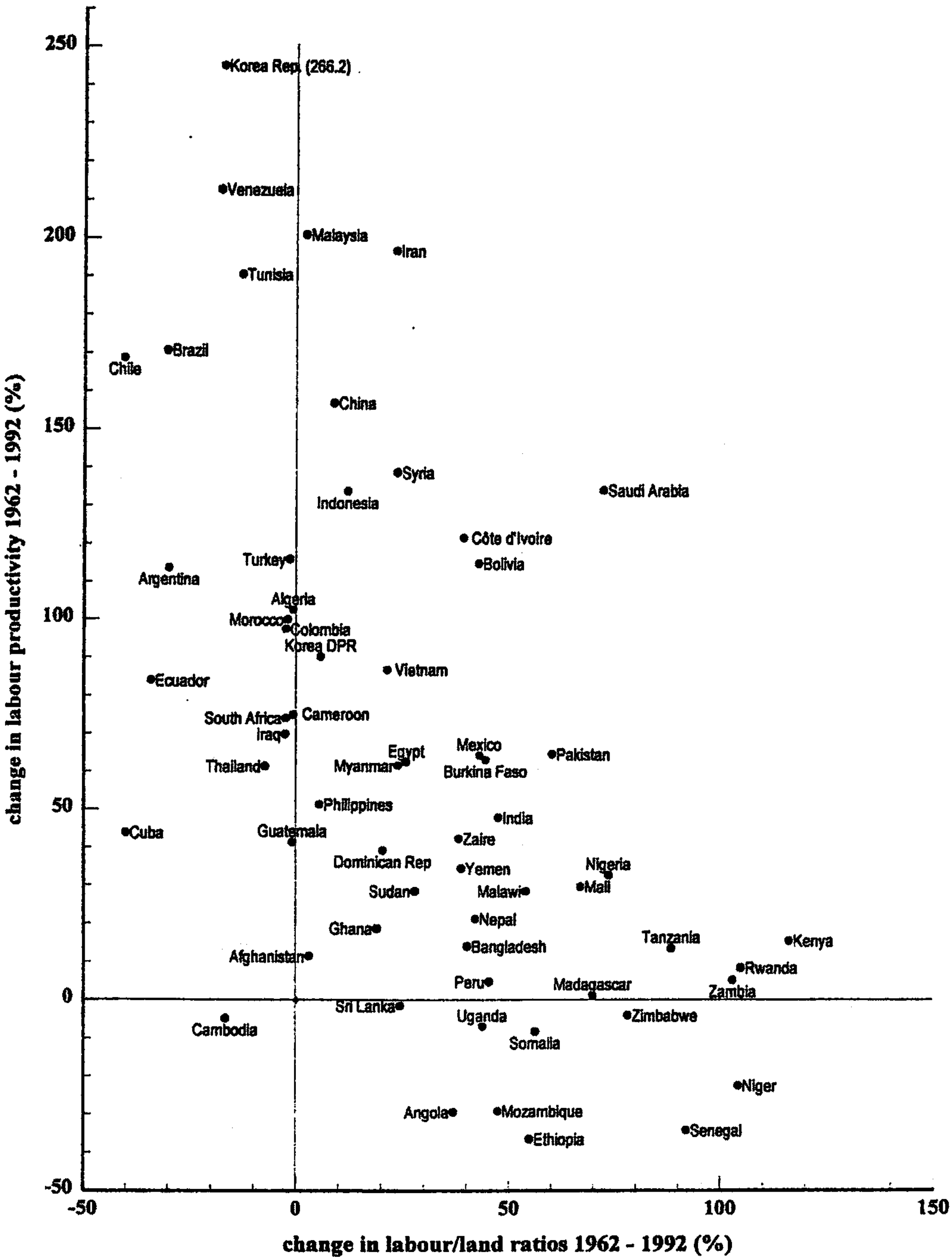
a According to per capita energy consumption in kilos of coal equivalent, number of telephones per thousand persons, life expectancy at birth and percentage of literates 15 years old and over. Group V has the highest technology level.
( ) Number of countries involved.
Source: Boserup (1981)

The disadvantage of Table 8.1 is that it includes only one country (India) with an overall low technology level and thus provides little information about the productivity of labour in SSA, where most countries have low technology levels. Cuffaro (1997) supplied more information about the labour productivity in SSA countries in comparison to countries with higher technology levels in Latin America and Asia. Figure 8.2 shows that between 1962 and 1992 most SSA countries experienced high increases in the ratios of labour to land due to rapid population growth. At the same time the labour productivity increased far less or even declined in some cases. Land use intensification due to population growth generally does not improve labour productivity when it is mainly based on labour-intensive technologies. High increases in labour productivity during the 1962-1992 period were mainly experienced in Asian and Latin American countries (Figure 8.2), most probably due to a higher use of capital-intensive technologies. A cross-country examination of current labour productivities revealed that SSA countries have in fact the lowest output per hour in the world (Giampietro, 1997).

Between the periods of initially declining and eventually increasing labour productivities in agriculture there is according to Boserup (1965) an intermediary stage where labour productivity in agriculture is declining while that of other activities is increasing. Instead of accepting the harder work involved in more intensive agriculture, people in rural areas will look for more rewarding and less arduous work in non-agricultural activities. Large-scale migrations to towns within the country take place in such periods and may prevent the necessary expansion of food production in the villages. In the absence of food imports such migrations can cause, however, higher prices for agricultural products which will stimulate agricultural development. Such a development took place in the western world during the 18th and 19th centuries (Koning, 1994).

Conelly (1994) showed that migrant wage employment and fishing reduced the available labour in agriculture and caused a process of disintensification on Rusinga Island in Kenya. In eastern Nigeria lower labour productivities in agriculture due to

Figure 8.2
Trends in labour productivity and labour/land ratios (1962-1992)



Source: Cuffaro (1997)

population pressure caused an increase in income derived from off-farm sources, which in fact more than compensated the decline in income from farming (Lagemann, 1977). In Rwanda Byiringiro and Reardon (1996) observed a "bottling-up" of labour on the smallest farms due to constraints to access to labour market opportunities, and perhaps barriers to entry into small business. Off-farm employment is mainly done by men in Rwanda and is already responsible for 80 percent of total income in the smallest farm-size quartile (Von Braun et al., 1991). These examples from SSA show that off-farm employment can have different effects on agriculture and does not necessarily lead to increased labour productivities in agriculture.

Cross-country examination of soil fertility management practices

In this section the Sukumaland case study is compared with thirteen selected case studies from SSA and Asia, sorted in order of increasing land use intensity, to see the important resemblances and differences in soil fertility management practices. Table 8.2 presents the soil fertility management practices for these selected case studies, as well as the intensity of land use, population density, annual rainfall, dominant soil types, market access, arable land per capita, livestock density, main food and cash crops, off-farm income and where possible the productivity of agricultural labour. The Mwanza and Shinyanga regions feature separately in Table 8.2 due to differences in population density and agroecological conditions, although the southern parts of the Kwimba and Geita districts in Mwanza region are more like Shinyanga region than like the main part of Mwanza region.

In general Table 8.2 confirms that organic soil fertility management practices are related to the intensity of land use (see also Figure 8.1). The intensity of land use is further related to the population density, which confirms that particular part of the Boserup hypothesis. However, Table 8.2 also displays a number of inconsistencies in relation to Boserup's conclusions. The use of kraal manure in Burkina Faso is for example higher than in other case studies with higher population densities. Binswanger and Pingali (1988) argued that Burkina Faso has in fact a relatively high population density when you look at the number of people per million kilocalories production potential. In the Sudan-Sahel zone of Burkina Faso the production potential is low due to limited annual rainfall and infertile sandy soils (Vierich and Stoop, 1990). A population density of 44 people per km^2 has already a high impact on the fertility of soils and requires fertility maintenance through adding organic material and/or mineral fertilizers (Dugué, 1989). In Mali-Sud, on the other hand, farmers use higher amounts of mineral fertilizers in comparison to case studies with higher population densities. This is related to the importance and institutional setting of the cash crop cotton in the farming systems of Mali-Sud. Due to the good institutional setting (extension, research, input supply, pricing, credit facilities, reliable markets) of the cotton sector in Mali-Sud, farmers adopted the use of mineral fertilizers in cotton. On the other hand less favourable institutional settings in the cotton sectors of Sukumaland (Tanzania) and Kenya discouraged the use of mineral fertilizers in cotton (Lele et al., 1989). Despite good institutional settings in the cotton sectors of Burkina Faso and Benin, mineral fertilizer use there remained modest. Most probably this is due to climatological problems such as nutrient leaching (Benin) and frequent dry spells (Burkina Faso), and the lower importance of cotton in the selected farming systems (Brouwers, 1993; Prudencio, 1993). The importance of

Table 8.2
A comparison of soil fertility management practices in Africa/Asia

Case Study	Land use Intens. (R-value)	Pop. Density (pers./ sq. km)	Rainfall (mm/ year)	Soils Dominant	Market Access	Arable land (ha/capita)	Livestock Density (LU/sq. km)	Main Foo Crops
Zaire (a) Kwango-Kwilu	15-50	23 (1983)	1500-1600	Sands	Very Poor	0.25	< 0.5 (Trypanosomiasis)	Cassava
Mali-Sud (b)	25-50	10-50 (1989)	600-1200	Loamy-Sands	Fair	0.75	15-40	Sorghum, Millets
Burkina Faso (c) Sudan-Sahel Zone	30-50	44 (1985)	600-800	Sands	Very Poor	0.44	23	Sorghum, Millets
Sukumaland (d) Shinyanga region	40-75	30-75 (1988)	700-900	Sandy-clay-Loams	Poor	0.45	35-90	Sorghum, Maize
Nigeria (e) Jos-Plateau	25-100	35-280 (1984)	1000-1500	Sandstones, Clays	Fair	0.6	low (Trypanosomiasis)	Millets, Sorghum
Nigeria (f) Imo State	30-100	200-1000 (1975)	2000-2500	Acid Sands	Good	0.05	low (Trypanosomiasis)	Cassava, Y
Kenya (g) Machakos district	50-100	150-400 (1990)	600-1000	Sandy-Clay-Loams	Good	0.23	20-40	Maize, Be
Sukumaland (h) Mwanza region	80-100	75-270 (1988)	800-1100	Sands	Fair	0.25-0.35	65-100	Cassava, R Sweet Pot
Benin (i) Adja-Plateau	80-100	80-250 (1985)	1100	Sands, Sandy-Loams	Fair	0.17-0.36	<0.5 (Trypanosomiasis)	Maize, Cassava
Nigeria (j) Kano-Zone	80-100	250-500	800	Sands	Good	0.23-0.33	15-30	Sorghum, Millets
Tanzania (k) Ukara Island	>100	200-300 (1988)	1200-1500	Loamy-Sands	Very Poor	0.15-0.20	70-100	Cassava, Sweet pot
Kenya (l) Kisii district	>100	500-725 (1996)	1300-2100	Volcanic-Loamy-Clays	Good	0.14-0.19	260-290 (cattle, goats, sheep)	Maize, Be
China (m) Tai Lake Region	180-190	>1000 (1985)	1100-1400	Loams, Clays	Good	0.07	150-200 (pigs, sheep, buffalos)	Rice, Whe
Indonesia (n) Lombok Island	200-250	300-900 (1990)	800-2000	Clays	Good	0.10-0.20	25-175	Rice, Soya
Bangladesh (o) Shyampur village	200-275	800 (1996)	2200	Sandy-Loams, Clay-Loams	Good	0.03-0.05	185	Rice

Sources: Based on;
(a) Fresco (1986)
(b) Defoer et al. (1998), van der Pol (1992), Kleene et al. (1989)
(c) Prudencio (1993), Vierich and Stoop (1990), van der Hoek et al. (1993), Dugué (1989), Breusers (1998)
(d) Meertens et al. (1996), Mashaka et al. (1992)
(e) Netting (1993), Netting et al. (1993), Phillips-Howard and Lyon (1994), Stone (1996)
(f) Lagemann (1977), Goldman (1993), Asadu and Enete (1997)
(g) Tiffen et al. (1994)

in Cash ps	Off-Farm Income as % of Total Income	Agric. Labour Prod. ($/day - crops only)	Mineral Fertilizers (kg/ha/yr)	Kraal Manure (tons/ha/yr)	Other soil fertility management methods
sava	30-60% Male outmigration	1.2	< 0.5	~0	no
ton	low	n.a.	30-50	0.3-0.5	kraal littering
›undnuts, ton, Maize	25-40% Male outmigration	0.9	<10	1.0-2.5	mulching, stone ridges
ton, Maize, e	low	1.7	1.0	<0.1	no
ns, Rice	low	n.a.	>50	n.a. stall-fed goats	terracing, compost
-palm, Cassava	40-75% Male outmigration	0.6	low	n.a. stall-fed goats	compost, night-soil, mulching
rticulture, Cotton, ffee, Fruits	50%	n.a.	~1.5	0.5-1.0 stall-fed goats/cattle	agroforestry, terracing, compost, mulching
e, Cotton, rticulture	can be 30%	1.4	1.5	~0.5	contour ridges
rticulture, tton, Oil-palm	can be >50% Young Male outmigr.	n.a.	low	~0	mulching
rticulture, ›undnuts	can be >75%	n.a.	25	2.0 stall-fed goats	agroforestry, compost, urban wastes
e	>50% Seasonal Male outm.	0.55-0.60	~0	4.5 stall-fed cattle/goats	compost, tied-ridges, green manure, terracing
ı, Coffee, Bananas, rticulture, Pyrethrum	70% Male outmigration	1.4	60	2.0-2.5 stall-fed livestock	agroforestry, mulching, contour strips
‹ Mulberries	65%	1.9	800-900	7.5-10 stall-fed livestock	night-soil
›acco, Chillies, ıter-melon	40%	2.0	370	~1.5	not mentioned
e, Horticulture	>50%	1.6	145	~1.5	compost

(h) Meertens et al. (1996), Meertens and Lupeja (1996)
(i) Brouwers (1993)
(j) Mortimore (1993), Harris (1998), Pingali et al. (1987)
(k) Ludwig (1967), Rounce and Thornton (1945), unpublished field trip Kilimo/FAO Plant Nutrition Programme in 1995
(l) Okoth-Ogendo and Oucho (1993), Smaling and Fresco (1993), de Jager et al. (1998), Daily Nation (1996)
(m) Ellis and Wang (1997), Ash (1998)
(n) Meindertsma (1997)
(o) Ali (1987), Islam and Taslim (1996), FAO (1997)

leaching can explain the low use of mineral fertilizers in the densely populated humid area situated on sandy soils in Imo State, Nigeria (Table 8.2). On Ukara island there is almost no use of mineral fertilizers due to very poor market access (Table 8.2). An important disadvantage of humid areas with low altitudes is the presence of tsetse flies, which cause the mortal sleeping disease (*Trypanosomiasis*) in cattle. The absence of cattle reduces the number of Livestock Units (LU) km^{-2} sharply. This greatly diminishes the availability of kraal manure ha^{-1} because the production of kraal manure from goats and sheep is only 10% in comparison to cattle. So the application of kraal manure ha^{-1} remains low in the densely populated areas on the Jos-Plateau in Nigeria, the Adja-Plateau in Benin and in the Imo State of Nigeria (Table 8.2). These examples from Table 8.2 show that ecology and economy can be important factors next to population density with regard to soil fertility management.

Table 8.2 shows further that the agricultural labour productivity related to the cultivation of crops can increase or decrease under higher population densities. The situations in Imo State (Nigeria), in the Sudan-Sahel zone (Burkina Faso) and on Ukara Island (Tanzania) appear to be examples of what Geertz (1968) described as agricultural involution, a tendency toward an over-elaboration of labour intensive methods. Ecological constraints such as leaching and *Trypanosomiasis* in Imo State limit the use of mineral fertilizers and cattle manure for the maintenance of soil fertility. Farmers try to maintain soil fertility with manure from stabled goats, compost, mulching and night-soil All these labour intensive methods lower the productivity of labour in crops cultivation and, according to Lagemann (1977), also fail to maintain soil fertility. Asadu and Enete (1997) reported, however, slight increases in organic matter and total nitrogen in the area with high population density due to the use of soil amendments. In the Sudan-Sahel zone of Burkina Faso ecological and economical constraints limit the use of external inputs and cause a decrease in labour productivity through high dependence on labour-intensive methods. The low agricultural labour productivity causes migration of young people from the rural areas. This exodus of the youth limits further adoption by households of labour-intensive methods for soil fertility enhancement (Enyong et al., 1999). On the basis of a bioeconomic model to the year 2030 for a village in sub-humid Burkina Faso, it is even proposed to promote the extensive use of remaining land, instead of intensifying already used land (Barbier, 1998). On Ukara Island as well the total dependence on labour intensive methods for soil fertility maintenance have lowered sharply the productivity of labour for the cultivation of crops. Geertz's (1968) basis for the concept of agricultural involution was a description of the cultivation of irrigated rice on Java island in Indonesia during the 1950s. However, the Green Revolution of the 1960s and 1970s supplied new technologies (high yielding rice varieties, mineral fertilizers and biocides) to rice farmers and these were able to raise the productivity of labour in rice cultivation. Table 8.2 shows that the cultivation of wet rice in Bangladesh, Indonesia and China has a relatively high labour productivity despite the very high population densities. Prior to the advent of mineral fertilizers, farmers in the Tai Lake Region of China (Ellis and Wang, 1997) used all kind of labour intensive organic fertilizers (compost, green manures, canal sludge, human and animal faeces, silkworm wastes) to maintain the soil fertility. Long term applications of these organic fertilizers actually increased soil organic matter and elevated the rice fields in a form of sedimentation. The productivity of labour, however, declined and local proverbs noted that human labour was cheaper than that of animals. From the 1970s onwards farmers were able to use mineral fertilizers in combination with high yielding rice and wheat varieties. By 1982 the growing of green manures, use of canal sludge and preparation of compost had vanished almost completely and labour productivity had increased considerably due to modern irrigation, tillage and mineral fertilizers (Ellis and Wang, 1997).

In almost all selected case studies incomes from off-farm employment are very important in relation to the total household income. Household members, especially (young) males, will be encouraged to look for off-farm employment when the labour productivity in agriculture is regarded as too low. Examples of this in Table 8.2 are the situations in the Kwango-Kwilu (Zaire), Sudan-Sahel Zone (Burkina Faso), Imo State (Nigeria) and Ukara Island (Tanzania). The availability of many types of employment in urban centres is an especially important factor for areas near to urban centres. Examples in Table 8.2 are the Mwanza region in Sukumaland, the Kano-Zone (Nigeria) and Machakos district (Kenya). In the case studies of Kisii district (Kenya), Bangladesh, Lombok Island (Indonesia), Tai Lake Region (China) and Adja Plateau (Benin), it is mainly the insufficient amount of arable land available per capita which forces household members to look for employment outside the farms. Collier (1981) criticized Geertz for not including off-farm employment in his analytical framework. According to Collier (1981), income per capita on Java Island, Indonesia, was more likely to increase due to significant additional income from off-farm employment. Meindertsma (1997) found that off-farm employment on Lombok Island, Indonesia, strengthened agriculture because income from off-farm employment was reinvested in farming. Similar developments took place in the Tai Lake Region of China (Ellis and Wang, 1997), where the development of local industry provided off-farm employment to farmers, who used part of the additional income for the adoption of high-yielding technologies. As a result living standards of rural households soared in the Tai Lake Region (Ellis and Wang, 1997). However, in Bangladesh (Islam and Taslim, 1996) non-agricultural sectors did not expand sufficiently in relation to population growth and this caused a tremendous pressure on agriculture. More people had to be employed in agriculture without the option of increasing the cultivated area. As a result there were no improvements in agricultural labour productivity and in the welfare of the households, despite the adoption of high yielding rice varieties and mineral fertilizers (Islam and Taslim, 1996).

In a few of the case studies off-farm employment is much less important for the total income of households (Table 8.2). Examples are the Shinyanga region of Sukumaland (Tanzania), Mali-Sud (Mali) and Jos-Plateau (Nigeria). It is remarkable that in all these examples the average area of land cultivated per capita is relatively high. In these areas higher population densities led to increases in farmsize with or without the assistance of oxploughs. Declining fallow periods reduced the soil fertility and yields of crops. To secure food requirements households decided to cultivate more land instead of improving the soil fertility of the existing fields. This process is described by some as land extensification in contrast to Boserup's land intensification (FAO, 1991; Bilsborrow and Geores, 1994). This contrast is incorrect because an increase in farmsize leads to a further reduction of the fallow period and is thus also an intensification of land use. The labour productivity is relatively high in these systems and this diminishes the need for off-farm employment. The relatively high labour productivity is partly a result of insufficient soil maintenance. Van der Pol (1992) calculated for Mali-Sud that 40% of the total income from agricultural activities is based on soil mining, a depletion of nutrients in the cultivated fields. Obviously this cannot go on forever.

Apart from food requirements, increases in farmsize can also be caused by growing land requirements for cash cropping (Gleave and White, 1969). This is indeed the case in Mali-Sud (Kleene et al., 1989) where households cultivate large fields with cotton, in the frontier area of the Jos Plateau in Nigeria (Netting et al., 1993) where farmers grow large fields of food crops for cash, and in the Shinyanga region of Sukumaland (Meertens et al., 1995) where farmers grow large areas of cotton, rice or maize for cash. Income from these large fields of cash crops reduces the need for significant additions from off-farm employment.

Discussion and conclusions concerning the capacities of INM/LEISA in developing sustainable agriculture in SSA under structural adjustment programmes

Cleaver (1993) remarks that the stimulus to Asia's Green Revolution, i.e. high population densities increasing the need for intensification, has now arrived in many parts of Africa. However, figures presented by Verheye (1997) show that only 23% of the potential arable area in Africa is presently cultivated. Annual cropping and multi-cropping are still uncommon in large parts of Africa and decades of efforts to introduce manures and crop residues for soil fertility maintenance have met with very limited success (Binswanger and Pingali, 1988). Farmers' investment in learning new methods and favourable policy environments are according to Pretty (1995) needed to obtain adoption of INM/LEISA techniques. The adoption of INM/LEISA techniques requires, however, more conducive factors than these two. Scoones and Toulmin (1993) list sufficient resource pressure (land scarcity/population pressure), favourable market conditions, on-farm availability of labour and skills, and socio-economic conditions that allow access to nutrients (secure tenure, access to livestock, stable relations between farmers/herders) as key conditions for sustainable management of nutrient cycles. Carter (1996) mentions maize dominance, poor soil fertility as defined by farmers, more than 1000 mm rainfall, soil pH higher than 5.5, tree scarcity, high population pressure, secure tenure, widespread ownership and confinement of livestock and dependence on agriculture for household income as factors which enable the adoption of alley-farming in West Africa. Clearly such complex sets of requirements restrict the appropriateness of INM/LEISA techniques in many parts of the world.

Only a few of the case studies in Table 8.2 (e.g. Kisii district, Kano-Zone and Machakos district) appear to be good examples of INM/LEISA successes in SSA. All these examples are characterized by relatively high land use intensity, high population density, good market access, medium to high livestock density and vicinity of large urban markets (horticulture). Tiffen and Mortimore (1992) stated that population increase was compatible with environmental recovery in Machakos district due to profitable markets, capital injections from off-farm employment and government efforts on education, extension and infrastructure. Agricultural success in these case studies appears to be a combination of favourable environments, promising locations and supportive infrastructure and goverment policies (Hyden et al., 1993). These sets of favourable conditions are, however, not present in large parts of SSA. The Shinyanga region of Sukumaland is one of those parts in SSA. Unlimited advocacy of INM/LEISA approaches in SSA will thus lead to many failures, which will resemble the failures of Green Revolution techniques and of the colonial, better farming methods on this part of the continent.

In the 1990s the concepts of sustainable agriculture and environmental degradation received ever increasing attention from development agencies and donors. Land degradation, a crucial topic in both concepts, featured highly in the international debates. Calculations of major nutrient balances for 38 countries in SSA showed that farmers are mining their soils through failing to compensate the extraction of nutrients from harvesting, erosion, leaching and gaseous losses (Stoorvogel and Smaling, 1990). For Tanzania as a whole it is also predicted that the productivity of soils will decline in the future through soil mining, soil erosion and soil acidity unless measures are taken to reverse this situation (Aune, 1995). Alarmed by the negative nutrient balances several people stress that there is an urgent need for soil fertility maintenance in SSA. Some people (Beets, 1990; Kieft, 1992; Pretty, 1997) advocate for this the LEISA approach while others (Lal and Singh, 1995; Borlaug and Dowswell, 1995; Larson and Frisvold, 1996; Mwangi, 1997; Breman, 1997; Koning et al., 1997; Reardon et al., 1997) feel that this requires an increase in the use of external inputs like mineral fertilizers.

Too narrow a focus on nutrient balance calculations can, however, lead to inappropriate recommendations to farmers. An example, provided in Chapter 7, is the recommendation to incorporate rice straw in Sukumaland rice cultivation systems on the basis of a nutrient balance calculation. Nutrient budget and balance models must make a lot of assumptions, and are often snapshot approaches with little understanding of dynamics of change and the role of socio-economic factors (Meertens et al., 1995; Scoones and Toulmin, 1998). Participation from farmers in the nutrient balance calculations often increases the understanding of socio-economic aspects. More insight into the dynamic changing patterns of farming systems requires historical literature research in addition to discussions with farmers. With a broader view negative nutrient balances (soil mining) may be seen as a necessary step towards sustainable agriculture (Gleave and White, 1969), as a result of adverse economic conditions (Stoop, 1991), a consequence of ecological constraints, an outcome of cash cropping, an effect of insufficient capital, labour, livestock or off-farm employment at the household level, a result of insufficient support for agriculture from SSA-countries, a consequence of restricted use of mineral fertilizers due to structural adjustment programmes, or a result of the competition from industrial countries which blocks agricultural development in SSA. In southern Mali the circumstances, goals and risk perceptions of farm households prolong soil mining practices because of allocative efficiency (Kuyvenhoven et al., 1998). A broader view assists in understanding such behaviour of farm households and prevents inappropriate recommendations to farmers. Such a broader view can maybe explain why de Jager et al. (1998) found no relation between farm income and nutrient balance in three districts in Kenya.

Beets (1990) sees sustainable farming systems as systems of agriculture largely based on local (mostly family) labour, low to moderate capital inputs, and low to modest levels of external inputs. Netting (1993) adds that indigenous smallholder systems based on high labour and low unrenewable energy inputs exhibit a feasible solution to the problems of resource exhaustion, pollution, and environmental degradation that so often accompany large-scale, energy-intensive agriculture. Pretty (1997) argues that such types of regenerative, low-input agriculture based on full farmer participation can be highly productive. These LEISA approaches are essentially the same models as were used in colonial times to rationalize African agriculture (Sumberg, 1998). Around 1945 Rounce (1949) advocated better farming methods for Sukumaland, which nowadays perfectly fit in LEISA approaches by Ravnborg (1990) and Budelman (1996) who suggest compost, green manures, agroforestry and night soil as alternative methods for soil fertility maintenance in Sukumaland. Fifty years after Rounce all these advocated farming methods are still largely rejected by farmers due to insufficient relevance to their socio-economic conditions and intensity of their farming systems (Meertens et al., 1996).

Most LEISA advocates seem to ignore the limits of their approaches and fail to investigate the reasons behind low adoption of LEISA type of strategies during colonial times. LEISA advocates for example seem to be largely unaware that farm methods mainly based on labour-intensive techniques can lead to impoverishment of farm households. Netting (1993) even tries to prove that the LEISA strategy will lead to higher labour productivities in farm and off-farm work. This chapter has, however, provided several examples from SSA and Asia where severe dependance on labour-intensive methods has led to decreased labour productivities. Ellis and Wang (1997) mention that the very intensive use of organic fertilizers in the Tai Lake Region of China was ecologically efficient but hardship for the people. So the adoption of organic methods by farmers is according to Koning et al. (1997) merely a defensive reaction induced by lack of alternatives and only helps farmers to subsist at a minimum level. Welfare improvements can only be expected when intensification is combined with technical or institutional innovation (Scherr et al., 1996). Pretty (1997) provides no information about the productivity of labour and its effect on the welfare of households in his successes of sustainable agriculture. It remains unclear if these successes are socio-economically viable and thus true examples of sustainable agriculture according to the criteria mentioned in Figure 1.1. For resource-poor farmers sustainable livelihoods come before sustainable environments (Low, 1993). So sustainable agriculture has to be in the first place socio-economically viable for households, otherwise farming will lead to involution accompanied by poverty, hunger and migration.

A low use of external inputs is according to LEISA approaches more appropriate for many farmers in LDC's because of their poor access to these inputs, which is still further limited by structural adjustment programmes (Kieft, 1992). Proponents of LEISA approaches do not plead for protection against structural adjustment programmes, but seem to use them as an argument for LEISA (Koning et al., 1997). Many farmers in SSA like to use external inputs such as mineral fertilizers and such wishes can not be ignored in a really participatory approach (Koning et al., 1997). According to Okali et al. (1994) there is among NGO's, however, a tendency to focus only on knowledge and local information they want to hear. LEISA advocates in such NGO's are simply not keen on external inputs due to their potentially damaging effect on the environment, and do not focus their attention on farmers' wishes to use these inputs. They also often incorrectly lump together mineral fertilizers with pesticides (Borlaug and Dowswell, 1995). LEISA approaches in the context of structural adjustment programmes will therefore lower further the use of mineral fertilizers in SSA. However, without external inputs LEISA can become a non-sustainable form of agriculture. To reverse this trend LEISA advocates have to start criticizing the structural adjustment programmes in SSA.

Labour productivities in the agricultural sectors of SSA-countries are among the lowest in the world. In 1990 the agricultural production costs in industrial countries were lower than in SSA due to a widening gap in labour productivities (Bairoch, 1997). Strategies for sustainable agriculture depending heavily on labour-intensive methods will lower labour productivities in SSA further, which will cause higher amounts of food imports by SSA-countries and as a result of that even less motivation for farmers to intensify their agriculture further.

Why are SSA-countries not allowed to support their agricultural sectors when industrial countries continue to do so by direct allowances or other means (Koning et al., 1997)? It seems that industrial countries even use the liberalization of world markets to exploit their advantage further and to prevent the development of local food production in the South (Röling et al., 1998). Removal of government support to the agricultural sector is according to IMF/World Bank needed to get central government budgets right. Balanced government budgets are in this view more important than balanced nutrient budgets and balanced household budgets.

Chapter 2 mentioned that in 1996/97 Tanzania allocated more than 30 per cent of the recurrent revenue to debt servicing. Could that money not have been used in a more constructive way? Smaling et al. (1996) argue that in the drier parts of West Africa, government-supported capital investments in nutrient stocks should be considered. The economic profitability of the final result, improved soil fertility, justifies such public support (Breman, 1997). Syers et al. (1996) state that adoption of INM technologies might require manipulation of market prices as a way to make these technologies attractive for farmers. The negative budgetary implications of such price policies (e.g. fertilizer subsidies or infrastructure investments) can be partly compensated through a higher collection of tax revenues from increased economic activities (Kruseman and Bade, 1998). Koning et al. (1997), however, find imposing tariffs on agricultural imports the best form of supporting farm income in West Africa.

In summary

- INM/LEISA approaches are not appropriate for farming systems in SSA characterized by relatively low land use intensity, low population density, low livestock density and/or poor market access

- Insufficient use of external inputs will turn LEISA into a non-sustainable form of agriculture characterized by low returns to labour and low levels of household welfare

- Negative nutrient balances do not always justify recommendations to farmers of immediate use of mineral fertilizers and/or organic fertilizers due to farm household (short-term) objectives fitting the prevalent socio-economic, ecological, public policy and international agricultural circumstances

- Active support from SSA-governments for their agricultural sectors in the form of subsidies/credits for external inputs, crop price improvements, and levies/duties on agricultural imports is needed to attain sustainable agriculture through INM/LEISA approaches and to protect their agricultural sectors against (often subsidized) competition from the industrial countries

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9 Conclusions and recommendations

Introduction

The introductory chapter already mentioned that sustainable agriculture needs to be ecologically sound and socio-economically viable over the long term (Smith and McDonald, 1998). It was also stated that, for assessing the sustainability of agriculture, it is necessary to look at biophysical, economic and social indicators at the field, farm, and watershed, as well as regional/national scales. In each of the chapters that followed, one or more of these indicators was investigated at one or more scales, in the context of rice production in Sukumaland. In this final chapter, all these aspects are brought together in a discussion of the overal **objective of this thesis,** *to explore if INM/LEISA approaches are capable of generating sustainable soil fertility management in the rice cultivation systems of Sukumaland, Tanzania, within the context of structural adjustment programmes.*

In connection with the objective of the thesis, most chapters concentrate on soil fertility management in rice cultivation. For sustainable rice cultivation in Sukumaland it is also necessary to investigate sustainability in relation to water and pests/diseases at the field level. Fortunately there is a low incidence of pests and diseases in the rice cultivation systems of Sukumaland. However, water availability can become a real threat to the sustainability of this indigenous water harvesting system due to the ongoing enlargements of rice areas in this semi-arid environment. It is anticipated that farmers will react to such threats by no longer putting new areas under rice cultivation.

It is important to note that the rice cultivation systems are only a part of the farming systems in Sukumaland. In many locations within Sukumaland, cassava, maize or sorghum are more important food crops, while cotton, maize or horticultural crops can be more important cash crops than rice. Sustainable agricultural development in Sukumaland depends on the performance of all these cropping systems and on the interactions of these cropping systems with livestock and other subsystems at the farm level. In this way we move from the rice field level to the farm level. From the farm level we further have to move to the watershed level and the region/nation levels to obtain a good view of the capacities of INM and LEISA to generate sustainable agriculture in Sukumaland under structural adjustment programmes.

In this chapter, we first give an overview of the main points from all previous chapters. This is followed by the main conclusions in relation to the objective of this thesis. The chapter ends with a recommendation of future policies to be followed in Sukumaland to attain sustainable agriculture.

Overview of previous chapters

Chapter 2 described rural development in Tanzania during the first years of independence, the ujamaa period, and the structural adjustment programmes. It showed how high increases in fertilizer prices and input availability problems in the villages are connected to the implementation of structural adjustment programmes in

Tanzania from 1986 onwards, through liberalization of agricultural inputs supply and pricing (removal of government subsidies). Productivity levels per rural capita for important food and cash crops in Tanzania are declining in the 1990s.

Chapter 3 presented the farming systems dynamics in Sukumaland for the past 100 years. People were attracted to Sukumaland due to its low incidence of human and animal diseases. The relatively high altitude, semi-arid climate and vast stretches of hardpan soils with only scattered trees reduced the dangers of malaria, tick-borne diseases and *Trypanosomiasis*. Cultivation was first restricted to the sandy upper parts of slopes because they are easy to prepare by handhoe. Increases in population density led to enlargements in farmsize in the direction of lower parts of slopes. According to Fresco (1995) this is nearly always the primary response to a growing population. Grazing areas for livestock were reduced by rice cultivation on the lowest parts of the slopes. Households with large herds therefore migrated to new, tsetse free areas and were able to have very large farms due to low population densities and the availability of ploughs and oxen. Migration to virgin areas is according to Stoop (1991) the second response to a growing population because it allows farmers to continue with low-input technologies. In the 1950s and 1960s household income increased strongly in Sukumaland due to financially rewarding cotton growing on large fields. In the 1970s and 1980s cotton growing became much less profitable and this led to cash crop diversification according to agroecological variations and distance to Mwanza town. Ongoing increases in population densities caused a continuing decrease in arable land and livestock units per capita, and shifts in crops grown. Less demanding (cassava) and higher yielding (rice, maize, cassava, sweet potatoes) crops were substituted for the traditional crops (sorghum, bulrush millet). Similar shifts were observed by Hyden et al. (1993) and Vierich and Stoop (1990) in other parts of SSA. These developments were not the same for all of the Mwanza and Shinyanga regions, due to differences in population density and agroecological conditions. At present there are some signs of agricultural intensification near Mwanza town, while extensive farming dominates in the remaining parts of Sukumaland. The presented yield levels for Usagara division are, however, based on only one season, and statements of emerging agricultural intensification near to Mwanza town may thus be premature.

The strong increase in rice cultivation during the last 25 years is remarkable against the background of low and highly unreliable rainfall in Sukumaland. Chapter 4 showed how farmers developed highly productive, rainfed, lowland rice systems solely on the basis of their knowledge of soils, rainfall patterns and topography, and on their experiments with water management systems, cultivars, planting and landpreparation methods. So farmer innovation and experimentation developed a highly productive cropping system despite unreliable and low rainfall. The increase in rice cultivation is an intensification of the farming systems triggered by a growing population. On the other hand it is also a diversification in cash cropping in response to the low profitability of cotton growing in the 1970s and 1980s. The cultivation of rice is more intensive in Mwanza region where transplanting takes place, while broadcasting dominates on the larger rice fields in Shinyanga region. Households grow rice both for food and for cash, but mainly for food in Mwanza region and mainly for cash in Shinyanga region. Water and weeds are the major production constraints, but low soil fertility is also a problem on the more sandy fields in Mwanza region. Yields have declined due to continuous cultivation, almost without any application of organic or mineral fertilizers. On the more clayey rice fields in Shinyanga region yields are, however, at present still satisfactory due to the relatively short period (10-20 years) of cultivation. However, in one out of three years farmers fail to get food and cash from rice due to insufficient, late or unreliable rainfall.

Results of on-farm research, presented in Chapter 5, showed that broadcasting 30 kg N ha^{-1} in the form of urea in wet rice fields at the tillering stage increased rice grain yields with 500-900 kg ha^{-1} in almost every type of rice field cultivated in Sukumaland. Higher doses than 30 kg N ha^{-1} were less economical at the crop and fertilizer prices of 1996. Chapter 6 demonstrated that despite the relatively high average productivity index for the low dose of urea in rice, there was almost no adoption by farmers. The main reasons for this were, according to the farmers, high increases in fertilizer prices and availability problems in the villages. Other reasons for not adopting urea use in rice were the unreliable rainfall (one out of three years farmers fail to cultivate rice due to insufficient/unreliable rainfall), absence of real need to use urea on the more clayey rice fields, and a lower ranking by farmers of the soil fertility problem in rice fields than anticipated by agricultural researchers following a FSRE methodology.

Failures in the adoption of urea in rice encouraged researchers and farmers in Sukumaland to look for alternative ways of improving soil fertility in rice fields. Chapter 7 presented some examples of research on the use of organic fertilizers in the rice cultivation of Sukumaland. The performance of green manures and multi-purpose trees were meager due to limited biomass production caused by the semi-arid climate. Half of the households in Sukumaland have no access to cattle manure, and the quality of this manure is low anyway due to open air collection and very low crop residue additions. A serious problem is also the relatively high amount of labour involved in transporting and incorporating bulky organic materials like kraal manure, green manure, rice husks and tree leaves in the relatively far and difficult to reach (crossing many bunds) rice fields. The required labour increase per hectare is not possible in Shinyanga region due to too low population densities, and furthermore not desired by households anywhere in Sukumaland due to the expected decrease in labour productivity. Apart from that, farmers with clayey rice fields see no need to invest that much in soil fertility management. A nutrient balance calculation for the rainfed lowland rice cultivation systems in Sukumaland showed no serious depletion rates for the major nutrients and this seems to give credit to the attitude of the farmers. Despite massive campaigns promoting the use of organic fertilizers in Sukumaland during the colonial period (Rounce, 1949) and recent attempts by the Tanzanian government (Minjas et al., 1987), there is still a very low adoption rate of organic fertilizers in rice. In fact the same applies to almost all cropping systems in Sukumaland. Only near to Mwanza town farmers are applying kraal manure and/or mineral fertilizers to horticultural crops and, to a lesser extent, maize/cassava fields. The applied quantities are, however, not sufficient to reach positive nutrient balances on these sandy upland soils (Budelman et al., 1996). Compared to rice fields in the valleys soil fertility degenerates even more quickly on the sandy upland soils due to the very low initial fertility.

In Chapter 8 the Sukumaland case study was compared with some selected case studies from SSA and Asia to see the important resemblances and differences in soil fertility management practices. INM/LEISA successes in SSA appeared to be characterized by relatively high land use intensity, high population density, medium to high livestock density, good market access and vicinity of large urban markets (horticulture). Active support from SSA-governments for their agricultural sectors is further needed to attain sustainable agriculture through INM/LEISA approaches and to protect their agricultural sectors against competition from the industrial countries.

Conclusions concerning the capacity of INM/LEISA approaches for generating sustainable soil fertility management in the rice cultivation systems of Sukumaland, Tanzania, within the context of structural adjustment programmes

Until now there has been almost no restitution of nutrients to the rice fields other than nutrients in atmospheric deposition, in sediments and in water from runoff, plus the fallow effect from failures to plant rice. Farmers with rice fields located on fertile clayey soils are still satisfied with the grain yield levels, and are not yet motivated to invest labour and cash in soil fertility maintenance. A nutrient balance calculation for these predominant types of rice soils shows no serious depletion of major nutrients in the short term. An explanation may be that rice fields in the valleys are soil fertility sinks, while fields in the upper parts of slopes serve as soil fertility sources. For sustainable rice cultivation in the future farmers will, however, have to invest considerably in soil fertility maintenance, especially for rice fields located on more sandy soils. This thesis shows that such investments are highly unlikely in the current situation of Sukumaland.

Some people argue that farmers' investment in learning new agricultural methods and favourable policy environments are the main factors required for achieving sustainable agriculture on the basis of low external inputs. The Sukumaland rice case study has shown that it really takes more than that. Some farmers in Sukumaland have full knowledge of the positive effects of cattle manure and the green manure used on nearby Ukara island but do not adopt these methods in their rice cultivation. This despite the fact that structural adjustment programmes in Tanzania are frustrating the use of external inputs in agriculture. The use of bulky organic fertilizers requires substantial additional labour inputs from households. In the absence of adequate external inputs, this causes a decrease in labour productivity and household welfare, a process largely ignored by many people advocating sustainable agriculture on the basis of low external inputs. Further problems are the low and unreliable rainfall, inadequate amount of cattle manure with a low quality, and no easy access to cattle manure for half of the households. In short, the use of locally available resources in Sukumaland rice cultivation is at present seriously constrained.

With less than 2 kg ha^{-1} yr^{-1} the consumption of mineral fertilizers in Sukumaland is very low, even for Tanzanian standards. Removal of government subsidies and privatization in the supply of agricultural inputs increased mineral fertilizer prices sharply at the village level. Midway through the 1990s this made the use of a low dose of urea in rice, and of mineral fertilizer in maize and cotton, unprofitable for farmers.

The **main conclusions** with regard to the objective of the thesis are therefore:

INM/LEISA approaches are currently not appropriate for generating sustainable soil fertility management in the rice cultivation systems of Sukumaland because

a) farmers are not able or inclined to supply the additional labour inputs involved in the use of organic fertilizers
b) the semi-arid climate and the short growing period available before rice (trans)planting severely limit the biomass production of organic fertilizers in rice fields themselves
c) quality and quantity of kraal manure available in the area is insufficient and only half of the households have easy access to it
d) the too high prices of agricultural inputs after the removal of government subsidies, and availability problems in the villages after liberalization of input supply, both the result of structural adjustment programmes, severely restrict the use of even low levels of external inputs by rice farming households
e) soil fertility problems in the majority of rice fields are according to the farmers not (yet) serious enough to justify soil fertility management investments

In addition:

- The huge increase in rice cultivation in Sukumaland is a good example of how farmers may adapt to increasing population densities, changes in market opportunities, and topography related soil fertility advantages

- Farmers' objectives in Sukumaland have often not been understood well enough by the colonial administration, Tanzanian government and IMF/World Bank. More farmer participation, especially in priority setting, is needed even in FSRE programmes to prevent such misunderstandings

Policy recommendations for sustainable rice cultivation/agriculture in Sukumaland

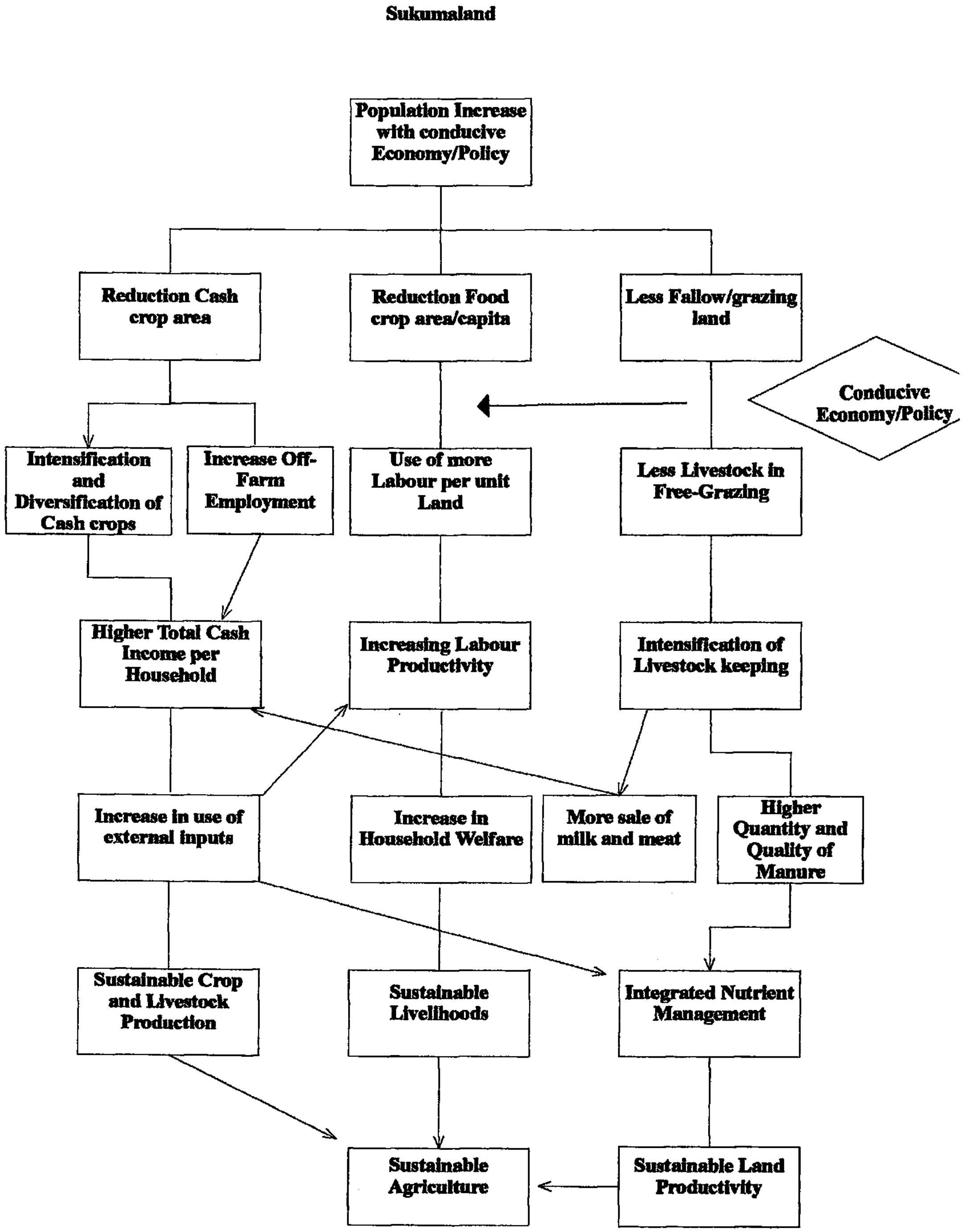
Any strategy for future sustainable rice cultivation and agriculture in Sukumaland, including INM or LEISA, has to be based on a thorough analysis of biophysical, socio-economic and public policy factors and their linkages. According to Lele and Stone (1989) adequate public policy measures are needed in the process of sustainable agricultural intensification. A so called policy-led sustainable agricultural intensification requires the following changes in the current situation of Sukumaland:

- improvement of infrastructure
- increased government support for agriculture
- reduced taxation in cotton crop sector
- reduced reliance on rice imports
- higher population densities
- intensive livestock keeping
- greater variety in off-farm employment

Figure 9.1 shows evolutionary paths for a growing population in Sukumaland with and without the above mentioned conducive economic and policy circumstances.

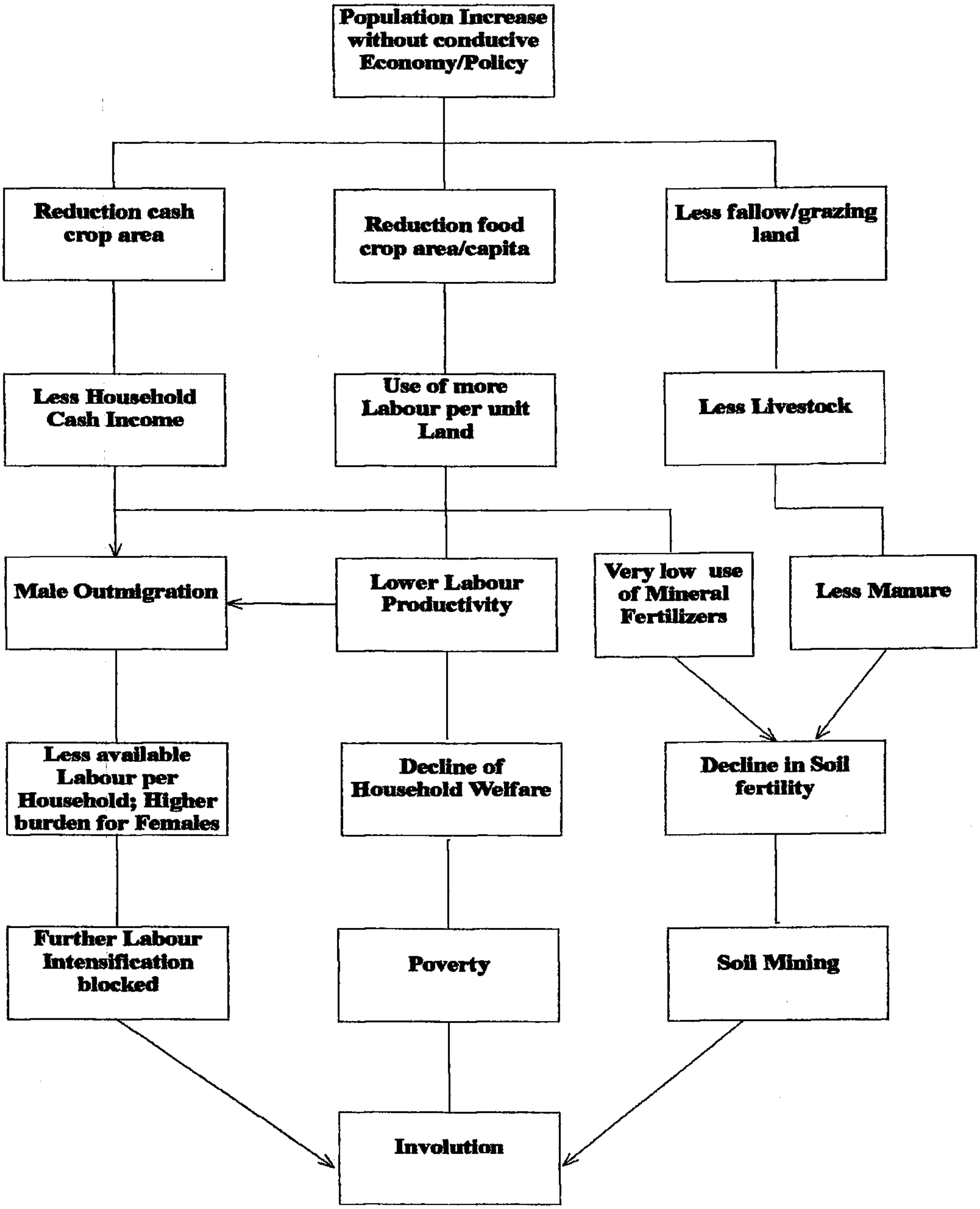
Chapter 2 and 6 showed that an **improvement of infrastructure**, especially roads, in Sukumaland is essential. At present there are only small stretches of tarmac roads so that during and after the rainy period many roads become inaccessable for heavy vehicles like lorries and buses. Supply of inputs like mineral fertilizers and buying of

Figure 9.1
Simplified evolutionary paths for a growing population in Sukumaland with and without conducive economic and policy circumstances



Source: based on Chapters 1 to 8 of this thesis

Sukumaland


Population Increase without conducive Economy/Policy
Reduction cash crop area
Reduction food crop area/capita
Less fallow/grazing land
Less Household Cash Income
Use of more Labour per unit Land
Less Livestock
Male Outmigration
Lower Labour Productivity
Very low use of Mineral Fertilizers
Less Manure
Less available Labour per Household; Higher burden for Females
Decline of Household Welfare
Decline in Soil fertility
Further Labour Intensification blocked
Poverty
Soil Mining
Involution

cotton, maize and rice in the villages becomes expensive and negatively affects the profit margins of farmers and traders alike. Without any improvement there will be no incentive for farmers to intensify their farming and no reason for private traders to supply agricultural inputs and buy agricultural products in the villages. At this time attempts are underway to tarmac the road between Mwanza and Dodoma via Shinyanga and to improve the rural feeder roads in Mwanza region. This is done under the Integrated Roads Project launched by the Tanzanian government and its international donors in 1991 (Putterman, 1995).

In Chapter 2 the World Bank (1994) was quoted as stating that **government support for agricultural research and extension** has been insufficient for a long time. Recent budgets show no improvement in that situation because the large civil service, the high debt servicing obligations and increasing social sector demands consume almost all recurrent revenue of the Tanzanian government. It is difficult to understand how structural adjustment programmes can alter this without any alleviation of debt servicing obligations. The World Bank and IMF allow furthermore no flexibility with regard to susidizing agricultural inputs or agriculture in general. So Tanzania and other SSA countries are supposed to follow another path than Asian countries like China, India and Indonesia, which actively support their agricultural sectors with subsidies (Verheye, 1997), or USA and Europe, which also subsidize the income of their farmers (Koning et al., 1997).

A **reduced taxation in the cotton crop sector** would increase the profit margin for cotton farmers in Sukumaland. Part of this additional cash income can be reinvested in agriculture through purchasing implements (ploughs, oxcarts) or inputs (mineral fertilizers, biocides). These implements and inputs can then also be used for other crops such as rice. Structural adjustment programmes have opened up the cotton sector in Tanzania for private companies and a healthy competition between these companies and the remaining cooperative unions is supposed to increase the efficiency in the cotton sector and the producer share of the world market price (World Bank, 1994).

Table 9.1
Rice (milled) production, imports and domestic consumption ('000 tonnes) in Tanzania (1992-1998)

Marketing Year	Domestic Production	Changes in Stocks	Net Imports	Domestic Consumption	% Consumption Imported
1992/93	255	-2	65	322	20
1993/94	417	-1	69	487	14
1994/95	399	+5	42	441	11
1995/96	470	-20	8	498	2
1996/97	477	+5	119	591	20
1997/98	358	+21	110	448	25

Sources: Food Security Department, Ministry of Agriculture and Cooperatives; Customs Department, Tanzania Revenue Authority

A reduced reliance on rice imports will enable the Tanzanian government to focus more on domestic rice production. Each year Tanzania is importing rice. Table 9.1 shows that rice imports formed 10-25% of the total Tanzanian rice consumption during 1992-98. These imports are often in the form of food grants from donors, especially Japan. In 1996 Japan gave a rice food grant of five hundred million yen to Tanzania. This grant was exclusively meant for the purchase of rice in Thailand and for the transport costs from Thailand to Tanzania. The world price for good quality milled rice from Thailand was 352 $/tonne in 1996 (FAO, 1997), while the average 1996 price for milled rice in Sukumaland was 417 $/tonne.[1] In Tanzania the Thailand rice turned out to be more expensive than the local Tanzanian rice due to the transport costs. Tax exemptions were needed to attract buyers and among these buyers was also a company from Mwanza.[2] This uneven competition reduced the market outlets of Sukumaland surplus rice and does not encourage the intensification of rice cultivation.

In 1997/98 there was a bumper rice harvest in Sukumaland while cotton production had largely failed. Exporting rice to Uganda and Kenya generated the much wanted cash income for the farmers, because the local rice market was depressed due to very low rice prices. Food security fears motivated the regional authorities to restrict this export of Sukumaland rice. However, the Food Security Department of the Ministry of Agriculture and Cooperatives lacked the money needed for buying this rice at competitive prices.[3] So export restrictions despite liberalization and government budget problems reduced the market outlets for Sukumaland rice even further in 1998. For the Tanzanian government rice imports are welcomed as an easy way to supply urban consumers, especially in Dar es Salaam, with relatively cheap food. No government resources are then needed to expand the domestic production of rice. However, the long-term cost of neglecting agricultural and rural development can be very high (Boserup, 1990). It would therefore be better to support producer prices of food crops through tariffs on agricultural imports (Koning et al., 1997). Clearly such international dimensions need to be included in the framework of Smith and McDonald (see Figure 1.1).

The INM and LEISA strategies require **higher population densities** in Sukumaland. Incorporation of green manures and crop residues, application of farmyard manure, preparation of compost and erosion control methods do all need higher labour investments from households. Chapter 8 showed that only households in areas with very high population densities and land use intensities have adopted these labour intensive methods. Decreasing farmsize and fallow land forced these households to invest more labour in soil fertility maintenance. Population densities in Shinyanga region and even in Mwanza region have to reach such very high levels before households in Sukumaland are inclined to adopt labour intensive methods for soil fertility maintenance on large parts of their farms.

Livestock keeping has to be intensified. Chapter 8 showed that livestock is stall-fed in almost all case studies with relatively high applications of livestock manure. High population densities diminish not only the farmsize and the fallow land, but also the grazing areas for livestock. Farmers have to compensate the reduction in grazing land through supplying alternative feeding materials to their livestock. For this purpose it is convenient to feed livestock in their stalls. The advantage of stall-feeding is that higher quantities of manure can be collected. Through adding crop residues and other organic material to the animal droppings an even higher quantity and quality of manure can be obtained. This system of stall-fed livestock requires, however, substantial higher labour inputs from the households. In Senegal Piraux et al. (1996) found that an increasingly integrated income-producing livestock farming is a deciding factor in ensuring household needs are met and better soil fertility management takes place.

A **greater variety in off-farm employment** opportunities in Sukumaland is required for a sustainable intensification of agriculture. High population densities diminish the farmsize and the total area available per household for food and cash crops. Cash is not only needed for household needs but also for farm investments. Chapter 8 showed that households in areas with very high population densities are depending mainly on income from off-farm employment to meet their cash requirements. In Rwanda Clay et al. (1998) observed that non-farm income enhances the capacity of households to follow the capital-led intensification path. Scarcity of non-farm employment caused a stagnation of agricultural productivity in Bangladesh (Islam and Taslim, 1996). Off-farm employment opportunities in Sukumaland will depend on the performance and growth of non-agricultural sectors in the nearby future.

In summary, sustainable rice cultivation and agriculture in Sukumaland on the basis of low external inputs needs a conducive economic and policy environment. Infrastructure improvement, especially of roads, will help increase farmgate crop prices and will make agricultural inputs available and their use profitable in the villages. Increased government support for agriculture will make farming more interesting socio-economically and will reduce the migration of rural people to urban areas. Healthy competition in the cotton sector will encourage farmers to intensify their production of cotton and other crops such as rice, and enable these farmers to obtain a higher cash income. Reduced rice imports can stimulate farmers to intensify their rice production and make Tanzania more self-sufficient in cereals. Good performance and growth of non-agricultural sectors in Sukumaland will enlarge off-farm employment opportunities and rural household incomes. Sustainable agriculture based on low external inputs requires further that population densities become even higher in all parts of Sukumaland. This is because additional labour is needed for the use of organic fertilizers, erosion control and the intensification of livestock keeping. Without a conducive economic and policy environment, population growth will lead to an intensification largely based on labour inputs and not external (capital) inputs. For Sukumaland this will cause a decline in labour productivity, diminished rural household welfare, increased soil mining, more poverty and hunger. Instead of an agricultural evolution there will be agricultural involution (Figure 9.1).

In case the above mentioned requirements for Sukumaland can be fulfilled, a good INM strategy in Sukumaland would be to use urea in the relatively more distant rice fields (high profitability) and farmyard manure in the nearby cassava/maize and cotton fields (less transport problems).

Notes

1 Unpublished information collected by the Kilimo/FAO Plant Nutrition Project in Mwanza region

2 This information was published in *The Observer* newspaper of July 21, 1996.

3 Personal observations during consultancy mission in October 1998.

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Summary

This thesis investigates options for sustainable rice cultivation and general agricultural development in the Mwanza and Shinyanga regions of northwestern Tanzania, often called Sukumaland due to the predominance of Wasukuma people. Generally Sukumaland has a semi-arid climate; agriculture is constrained by unreliable and low rainfall. In the past fifty years the population density has doubled in most areas. This has triggered several changes in farming systems. One important change is a reduction of grasslands in the valleys, due to increased cultivation of rice. Rice cultivation systems in Sukumaland serve here as a case study that allows the investigation of the interplay of social, economic and biophysical sustainability factors at field, farm, watershed and regional/national levels and their importance to the development of sustainable agriculture. Because soil fertility management is currently more important to sustainable rice cultivation in Sukumaland than water use efficiency or pest and disease susceptibility, it is the focus of the investigation.

Economic reform programmes known as structural adjustment programmes started in Tanzania around 1986, guided by the International Monetary Fund (IMF) and the World Bank. These programmes required drastic changes in Tanzanian national economic policies and had great impact on the marketing of agricultural outputs and inputs. Liberalized markets and private traders were expected to improve the agricultural sector via a much needed intensification of agriculture, involving higher consumption of mineral fertilizers, herbicides and pesticides. However, the 'liberalization' of international agricultural trade provided only a limited increase in access to developed country (DC) markets for less developed countries (LDCs) like Tanzania, and included few restrictions on the dumping of agricultural products by DCs. Farmers in LDCs cannot compete with farmers in DCs, and this lack of market opportunities, in combination with low agricultural prices and the low purchasing power of LDC consumers, pose major constraints on LDC food security. Specific data for Tanzania show that for this country the per capita food production increased in the 1970s, stabilized in the 1980s and started to decline in the 1990s. From a national point of view this is obviously not sustainable agricultural development.

The gradual process of soil nutrient depletion in many parts of sub-Saharan Africa (SSA) is thought to be a reason, though rather hidden, for slow agricultural growth in the face of high increases in population. An integrated nutrient management (INM) strategy, which combines the use of locally available resources with the use of external inputs and includes both management practices to save nutrients from being lost from the system and interventions to add nutrients from outside, has been advocated to increase production and develop sustainable agriculture in SSA. INM methods are one of the important strategies of low external input and sustainable agriculture (LEISA) policies. The LEISA approach is aimed at making optimal use of local available resources, adding limited external inputs and using them in the most efficient way. In managing soil fertility, low inputs of mineral fertilizers must be combined with applications of farmyard manure and, where applicable, green manures, compost, agroforestry and erosion control. The expected result is sustainable increases in production.

The objective of this thesis is to evaluate whether it is feasible for farm households in the Sukumaland rice cultivation systems to adopt INM and LEISA, given the current economic climate fostered by structural adjustment programmes. More generally, whether farm households in SSA countries can adopt INM/LEISA as a way of generating sustainable agricultural development in the context of liberalization of international agricultural trade, structural adjustment programmes, and fast population growth is examined. It must be noted that in many locations within Sukumaland, cassava, maize or sorghum are more important food crops than rice; cotton, maize or horticultural crops can be more important cash crops than rice. Just as elsewhere, sustainable agricultural development in Sukumaland depends on the performance of all cropping systems present, and on the interactions of these cropping systems with livestock and other subsystems at the farm level.

When performance in the food and cash crop sectors of Tanzania and the availability and consumption of agricultural inputs in 1986-1996 are compared with periods prior to IMF/World Bank backed reform, the positive developments of the first five years of reform appear not to be sustainable. At present, rural productivity levels per capita for important food and cash crops are declining. High increases in fertilizer prices and input availability problems in the villages are related to liberalization of agricultural input supply and pricing. The removal of subsidies on agricultural inputs from 1991 onwards is crucial in explaining the decline in production of maize, the main food crop in Tanzania. Structural adjustment programmes usually include far reaching reductions in the role of government. However, adequate government involvement may be necessary to ensure greater use of agricultural inputs and thus improved performance of the agricultural sector in Tanzania.

In Sukumaland, historical material makes it possible to put current conditions in an historical context. A description of farming systems dynamics in Sukumaland over the past 100 years shows that people were attracted to the area by its low incidence of human and animal diseases. Cultivation was first restricted to the sandy upper parts of slopes because they are easy to prepare by hand hoe. Increases in population density led to enlargements in farm size directed towards the lower parts of slopes. Rice cultivation in these areas reduced grazing space for livestock. Households with large herds migrated to new, tsetse free areas; large farms were made possible by the availability of ploughs and oxen. In the 1950s and 1960s there were strong increases in household income in Sukumaland due to extensive, financially rewarding cotton growing. In the 1970s and 1980s this became much less profitable, leading to diversification in cash crops in accord with agroecological variations and distance to Mwanza town. Ongoing increases in population density caused a decrease in arable land and livestock units per capita, plus shifts in crops grown. Less demanding (cassava) and higher yield (rice, maize, cassava, sweet potatoes) crops were substituted for the traditional crops (sorghum, bulrush millet). These developments varied across the Mwanza and Shinyanga regions, due to differences in population density and agroecological conditions. At present there are signs of agricultural intensification near Mwanza town, while extensive farming dominates in the remaining parts of Sukumaland.

Recent agricultural surveys conducted in Sukumaland have drawn attention to the importance of rainfed, lowland rice in the farming systems studied. More than a third of rice produced in Tanzania comes from Sukumaland. Farmers increased their rice production quickly when rice cultivation became more profitable in comparison to cotton and other crops, as well as more popular as a food crop because it can produce high amounts of calories on small pieces of land. The strong increase in rice cultivation during the last 25 years is remarkable, given the low and highly unreliable rainfall in Sukumaland. Farmers have developed highly productive rainfed, lowland rice systems solely on the basis of their knowledge of soils, rainfall patterns and topography, and on their experiments with water management systems, cultivars, and planting and land preparation methods. Rice management practices closely follow differences in ecology and household characteristics. Selection of rice cultivars is largely determined by water conditions in the field. The cultivation of rice is more intensive in Mwanza region, where transplanting takes place; on the larger rice fields in Shinyanga region, broadcasting predominates. Households grow rice for both food and cash - mainly for food in Mwanza region and mainly for cash in Shinyanga region. Water and weeds are the major production constraints, but low soil fertility is also a problem on the sandier fields of Mwanza region. Yields have declined due to continuous cultivation, with almost no application of organic or mineral fertilizers. On the more clayey rice fields in Shinyanga region yields are, however, still satisfactory at present due to the relatively short period (10-20 years) of cultivation. However, in one out of three years farmers fail to get food and cash from rice due to insufficient, too late or too unreliable rainfall.

In response to farmers' complaints about declining rice yields, on-farm soil fertility research was carried out in the rice fields of Sukumaland between 1990 and 1996, using a Farming Systems Research/Extension (FSRE) methodology. The decline was thought to be related to a decrease in soil fertility. On-farm research showed that broadcasting 30 kg N ha^{-1} in the form of urea in wet rice fields at the tillering stage increased rice grain yields by 500-900 kg ha^{-1} in almost every type of rice field cultivated in Sukumaland. Doses higher than 30 kg N ha^{-1} were less economical at 1996 prices for crops and fertilizers. The crop yield response to urea was better when rice plants were at the maximum tillering stage, when water depths were less than 15 cm at application, and when the sand content of fields was higher. The relatively small differences each year in response per field did not justify multiple extension messages. A single dose of 30 kg N ha^{-1} in the form of urea to rice at tillering was thus recommended for Sukumaland as a whole.

Despite the relatively high average productivity index for a low dose of urea in rice, there was almost no adoption by farmers. The main factors were problems in the availability of urea in villages and decreasing profitability of the rice-urea technology, due to IMF/World Bank instigated reform measures. Non-adoption was also due to absence of real need to use urea on the more clayey rice fields; poor involvement of the extension service; confusing research messages related to rice soil fertility management; the high degree of uncertainty in Sukumaland farming systems; and low participation of farmers during priority setting for on-farm activities. Effective adoption of agricultural technologies generated by an FSRE methodology calls for strong, institutionalized links with the extension service, commodity research and policy makers. Better coordination of activities between donors and governments is an essential precondition to make such links work.

Failures in the adoption of use of urea in rice encouraged researchers and farmers in Sukumaland to look for alternative ways to improve soil fertility in rice fields. Research has been done on the use of locally available resources such as kraal manure and rice husks, and the introduction of green manure and multipurpose trees as an alternative to urea. The performance of green manures and multi-purpose trees was meagre due to limited potential for biomass production in the semi-arid climate. Half of the households in Sukumaland have no easy access to cattle manure, and in any case the quality of the available manure is low, due to open air collection and very low addition of crop residues. The relatively large amount of labour involved in transporting and incorporating bulky organic materials like kraal manure, green manure, rice husks and tree leaves in the relatively far and less easily accessible rice fields is also a serious problem. The increase in labour required per hectare is difficult to realize in the thinly populated Shinyanga region, and furthermore is not seen as desirable by households anywhere in Sukumaland, due to the expected decrease in labour productivity. Apart from that, farmers with clayey rice fields see no need to invest so much in soil fertility management. A nutrient balance calculation for the rainfed lowland rice cultivation systems in Sukumaland gave no serious depletion rates for major nutrients, which seems to support the farmers' attitude. Despite massive campaigns promoting the use of organic fertilizers in Sukumaland during the colonial period and recent attempts by the Tanzanian government, the adoption rate is still very low in almost all cropping systems. Only near Mwanza town are farmers applying kraal manure to horticultural crops and, to a lesser extent, maize/cassava fields. The quantities applied are, however, not sufficient to achieve positive nutrient balances on these sandy upland soils.

A review of the literature suggests that INM/LEISA successes in SSA are characterized by relatively high intensity of land use, high population density, medium to high livestock density, good market access and presence of large urban markets (in particular for horticultural products) in the vicinity. Further, the active support of SSA governments for their agricultural sectors will be needed if sustainable agriculture is to be attained through INM/LEISA approaches, as well as active intervention to protect their agricultural sectors against competition from industrial countries. INM/LEISA approaches are not appropriate for SSA farming systems that lack these characteristics. Several examples from SSA and Asia show that severe dependence on labour-intensive methods may lead to decreases in labour productivity. LEISA advocates seem to be largely unaware that farming methods based primarily on labour-intensive techniques can lead to the impoverishment of farm households. For resource-poor farmers, sustainable agriculture must first of all be socio-economically viable. Insufficient use of external inputs can turn LEISA into a non-sustainable form of agriculture; therefore LEISA advocates should take a critical look at the impact of structural adjustment programmes in SSA.

The main conclusion of this thesis is that INM/LEISA approaches are currently not an appropriate way to generate sustainable soil fertility management in the rice cultivation systems of Sukumaland. Farmers with rice fields located on fertile clayey soils are still satisfied with their grain yields, and are not yet motivated to invest labour and cash in soil fertility maintenance. However, especially in rice fields located on sandier soils, in the future farmers will have to invest considerably in soil fertility maintenance to achieve sustainable rice cultivation. The current situation in Sukumaland makes such investments highly unlikely. The huge increase in rice cultivation in Sukumaland is on the other hand a good example of farmer adaptation to increasing population densities, changes in market opportunities, and soil fertility advantages in the valleys. Negative nutrient balances furthermore do not always justify recommendations to farmers that involve the immediate use of mineral fertilizers and/or organic fertilizers. More farmer participation, especially in priority setting, is necessary to prevent misunderstandings regarding farmers' objectives.

Any strategy for future sustainable rice cultivation and agriculture in Sukumaland, including INM or LEISA, must be based on a thorough analysis of biophysical, socio-economic and public policy factors and their linkages. Such a strategy requires a conducive economic and policy environment. In Sukumaland this will require improvements in infrastructure, increased government support to agriculture, reduced taxation in the cotton crop sector, reduced reliance on rice imports, higher population densities, intensive livestock keeping and a greater variety of off-farm employment. A good INM strategy in Sukumaland would then be to use urea in rice, and farmyard manure in the nearby cassava/maize and cotton fields. Without a conducive economic and policy environment, population growth in Sukumaland will lead to an intensification largely based on labour inputs. Instead of agricultural evolution, agricultural involution will be the result.

Summary in Swahili (Muhtasari)

Jarida hili la Shahada ya juu ya falsafa katika fani ya Utafiti na ushauri kilimo linatathmini mbinu bora za kilimo cha mpunga na maendeleo ya kilimo kwa ujumla katika mikoa ya Mwanza na Shinyanga, maarufu kama Usukumani kutokana na kuwa na wakazi wengi wa kabila la Wasukuma. Eneo hili kwa ujumla ni kame na kilimo kinatatizwa na kutokuwa na mvua za uhakika. Katika kipindi cha miaka hamsini iliyopita idadi ya watu iliongezeka maradufu. Hili lilisukuma kasi ya mageuzi ya mifumo ya kilimo katika mikoa hiyo. Badiliko mojawapo ni ongezeko kubwa la matumizi ya mbuga kwa ajili ya kilimo cha mpunga. Mageuzi hayo ya mifumo ya kilimo cha mpunga ndiyo yanayotumika kama mada kuu katika kutathmini changamoto la mbinyo wa kijamii, uchumi na mali asili kuanzia ngazi ya chini hadi ngazi ya Taifa katika kuchochea maendeleo ya kilimo na ustawi wake. Tathmini hiyo inakazia zaidi suala la utunzaji wa rutuba ya udongo kuliko umwagiliaji na uzuiaji wa wadudu kutokana na umuhimu mkubwa uliopo hivi sasa katika kustawisha uzalishaji wa mpunga Usukumani.

Mnamo mwaka 1986 mipango ya kufufua uchumi ilianzishwa na kuendeshwa na Shirika la Kimataifa la fedha, IMF, na Benki ya Dunia. Mipango hiyo ilishinikiza mageuzi makubwa na ya haraka katika sera za uchumi za Taifa, na imetoa changamoto kubwa katika sekta ya kilimo hasa kwa upande wa pembejeo na masoko. Sera ya soko huria na wanunuzi binafsi wa mazao ililenga kuboresha kilimo kwa kuongeza uzalishaji kwa ekari, kwa kuzidisha matumizi ya pembejeo hasa mbolea na madawa ya wadudu na magugu. Hata hivyo, katika ngazi ya kimataifa sera ya soko huria haikutoa nafasi ya kutosha kwa nchi zinazoendelea kama Tanzania ili ziweze kuuza mazao yao katika soko la kimataifa. Vile vile sera hizo hazikuweza kuzuia nchi zilizoendelea kutumia nchi zinazoendelea kama dampo la bidhaa zao. Suala lingine ni kwamba wakulima wa nchi zinazoendelea hawawezi kutoa ushindani wa kibiashara kwa wakulima wa nchi zilizoendelea, kutokana na kutokuwa na nafasi sawa za kisoko na kibiashara. Kunyimwa nafasi sawa katika soko la dunia na bei ndogo za mazao anayopewa mkulima wa nchi zinazoendelea ni baadhi ya mambo yanayosababisha hali ya upungufu wa chakula katika nchi zinazoendelea. Takwimu zinaonyesha kuwa uzalishaji wa mazao ya chakula kwa kila mkazi nchini ziliongezeka miaka ya sabini, hazikubadilika miaka ya themanini na zimepungua miaka ya tisini. Kwa mtazamo wa ngazi ya Taifa, masuala hayo hayawezi kuchukuliwa kama yanaonyesha ustawi wa kilimo.

Sababu nyingine ambayo haiko wazi, ya kusuasua kwa maendeleo ya kilimo yanapowianishwa na ongezeko la watu ni kuendelea kupungua taratibu kwa virutubisho vya mazao katika ardhi nyingi kusini mwa jangwa la Sahara. Mbinu mseto (INM) za utunzaji wa rutuba ya udongo, zinazochanganya matumizi ya mali asili na zile za kutoka nje, na mikakati ya kuzuia uchakavu wa ardhi zinashauriwa ili kuongeza uzalishaji katika nchi hizo. Sera za miradi kama LEISA, zingeweza kuchukuliwa kama mwongozo katika kukazia mbinu za kushauri mbinu mseto za kudumisha uzalishaji. LEISA inakazia udhibiti wa matumizi ya mbolea kutoka nje. Hili linawezekana tu iwapo matumizi ya samadi, mboji, kilimo misitu, na udhibiti wa mmomonyoko wa udongo vitaongezeka. Matokeo yake bila shaka yatakuwa ustawi na ongezeko la uzalishaji.

Lengo la jarida hili ni kuchanganua iwapo mbinu mseto (INM & LEISA) zinaweza kukaririwa na kaya za Kisukuma katika mfumo wa kilimo cha mpunga, katika mazingira ya sasa ya nayosababishwa na sera za kurekebisha uchumi. Pia inachunguzwa kwa ujumla iwapo wakulima Kusini mwa jangwa la Sahara wanaweza kukariri mbinu za INM/LEISA ili kuendeleza uzalishaji na ustawi wa kilimo,katika mazingira hayo hayo ya soko huria la mazao ya kilimo, urekebishaji uchumi, na ongezeko kubwa la watu. Mbali ya mpunga mazao mengine kama mihogo, mahindi na mtama yanaweza kuwa ya muhimu zaidi kwa chakula katika baadhi ya sehemu. Pia pamba, mahindi na mazao ya bustani yanaweza kuwa ya muhimu zaidi kwa biashara kuliko mpunga.Kwa hiyo ustawi na maendeleo ya kilimo kwa Usukumani na sehemu nyinginezo unategemea ustawi wa mifumo yote ya uzalishaji kwa pamoja, bila kusahau mifugo.

Jarida pia linalinganisha mwenendo wa sekta za mazao ya chakula na biashara, na upatikanaji na matumizi ya pembejeo katika kipindi cha 1986–96 na vipindi kabla ya mageuzi ya sera za uchumi yaliyosimamiwa na IMF na Benki ya dunia. Ufanisi uliopatikana katika miaka mitano ya kwanza ya mageuzi ya sera za uchumi unaonekana kuwa haukuwa wa kudumu. Hivi sasa uzalishaji wa mazao ya chakula na biashara kwa wakazi wa vijijini unashuka. Pembejeo vijijini zimepanda bei na zinapatikana kwa shida. Kufutwa kwa ruzuku za pembejeo za kilimo kunaeleza kikamilifu kupungua kwa uzalishaji wa mahindi ambalo ni zao kuu la chakula kwa Tanzania. Programu ya mageuzi imepunguza ushiriki wa Serikali katika sekta za uzalishaji na utoaji huduma, ingawaje kwa Tanzania mchango wa Serikali bado unahitajika ili kuhakikisha ustawi na maendeleo ya sekta ya kilimo.

Maelezo ya mwenendo wa mabadiliko ya mifumo ya kilimo katika nchi ya Usukuma kwa miaka 100 iliyopita yanaonyesha kuwa watu walihamia maeneo hayo kutokana na kutokuwa na matatizo makubwa ya magonjwa ya binadamu na mifugo. Mwanzoni mashamba yalitanda sehemu za mwinuko tu, ambapo udongo ulilimika kirahisi kwa jembe la mkono. Ongezeko la watu na ukubwa wa kaya vimesukuma mashamba mbugani (kilimo cha mpunga), hivyo kupunguza eneo la kuchungia. Kaya zenye mifugo mingi zililazimika kuhamia sehemu zingine, ambako waliweza kufungua mashamba makubwa kwa kusaidiwa na jembe la kukokotwa na ng'ombe. Katika miaka ya 50 na 60, pato la wakulima wa Usukumani liliongezeka sana kutokana na mauzo ya pamba. Miaka ya 70 na 80 pamba haikuwa na bei nzuri hivyo wakulima wakaanza kujishughulisha na mazao mengine. Ongezeko kubwa la watu linaloendelea kuwepo limesababisha kupungua kwa ardhi ya kilimo na mifugo, na mabadiliko katika umuhimu wa baadhi ya mazao katika jamii.lisilohitaji huduma nyingi (mihogo) na mazao yanayozalisha kwa uwingi zaidi (mpunga, mahindi, mihogo na viazi) yalichukua nafasi ya mazao ya asili.haya yalitofautiana kutoka sehemu moja hadi nyingine kutegemea hali ya hewa na mbinyo wa idadi ya watu. Sehemu zilizo karibu na Mwanza mjini ambako maeneo ya kilimo siyo makubwa, uzalishaji kwa eneo unazingatiwa zaidi, wakati katika maeneo yaliyobaki, uzalishaji kwa kutanua eneo la kilimo ndio unaotawala.

Utafiti uliofanyika karibuni umetoa mwanga kuhusu umuhimu wa kilimo cha mpunga katika mabonde ya Usukumani. Theluthi ya mpunga wote unaozalishwa Tanzania unatoka Usukumani. Wakulima walipanua kilimo cha mpunga baada ya kuona kuwa kilikuwa na faida zaidi kuliko pamba na mazao mengine, kuzoeleka kama zao la chakula na kutokana na uwezo wake mkubwa katika uzalishaji. Ongezeko kubwa la uzalishaji mpunga katika eneo hili lisilo na mvua za uhakika ni kitendawili kwa walio wengi. Wakulima wamefanikisha hilo kwa kutumia ujuzi wao juu ya udongo, mwinuko na mtandao wa hali ya mvua; uandaaji wa mashamba utunzaji wa maji, uchaguzi wa aina za mbegu kutegemea upatikanaji wa maji, na matunzo mengineyo, ambayo yanategemea sana mazingira shamba na kaya yenyewe. Tofauti ya kilimo cha mpunga kati ya Mwanza na Sinyanga ni kuwa Mwanza mashamba ni madogo zaidi, udongo ni wa kichanga zaidi (hivyo wana tatizo la rutuba), utunzaji ni wa hali ya juu zaidi ambako upandikizaji unafanyika kwa uwingi zaidi, na mpunga mwingi ni kwa ajili ya chakula. Kwa upande wa Shinyanga mashamba ni makubwa zaidi, upandaji ni kwa njia ya kumwaga mbegu, sehemu kubwa ya uzalishaji ni kwa ajili ya kuuza. Tatizo la kupungua kwa uzalishaji liko zaidi Mwanza kutokana na kulima mfululizo bila kuweka mbolea. Kwa upande wa Shinyanga, mashamba mengi bado ni mapya na udongo ni wa mbuga wenye rutuba zaidi. Hata hivyo mara moja katika miaka mitatu wakulima hushindwa kuzalisha kutokana na kuchelewa sana au kukosekana kabisa kwa mvua.

Utafiti kuhusu matumizi ya mbolea kwenye mpunga, ulioendeshwa na mradi wa FSR kwa kushirikiana na wakulima kati ya 1990 na 1996, ulifanyika ili kujibu kilio cha wakulima kuhusu kushuka kwa uzalishaji wa mpunga. Kushuka huko kulihusishwa na kupungua kwa rutuba ya udongo. Matokeo ya utafiti huo yalionyesha kuwa mbolea ya Urea huongeza mavuno kwa kati ya kilo 500 na 900 kwa hektari, iwapo itawekwa kwa kiwango cha kadiri ya mfuko mmoja na theluthi moja kwa hektari, (30 kg N ha^{-1}) kwenye shamba lenye maji kiasi, na wakati mpunga unatoa machipukizi. Kwa bei za mbolea za mwaka 1996, viwango vikubwa zaidi vilionekana kutolipa. Matokeo ya utafiti huo yameonyesha kuwa ushauri huo unafaa kwa eneo lote la Usukumani.

Pamoja na ongezeko hilo la mavuno kwa kutumia mbolea, ushauri huo haukutiliwa maanani na wakulima. Sababu za kutofuatwa ushauri huo ni kukosekana kwa mbolea vijijini na kupanda kwa bei ya mbolea ambako kumetokana na sera mbinyo za IMF na Benki ya dunia. Wakulima kutoona umuhimu halisi wa kutumia mbolea hasa kwenye mbuga, kutoshirikishwa idara ya ushauri kwa wakulima katika kusambaza ushauri huo, wasiwasi wa kukosekana kwa mvua pia vimechanga kutopokelewa kwa utaalamu huo. Sababu nyingine muhimu ni kutoshirikishwa kikamilifu kwa wakulima katika kuchambua matatizo yao na kupanga jinsi ya kuyatatua kutokana na umuhimu wake. Kuna umuhimu mkubwa wa kuleta mshikamano na kuoanisha shughuli za FSR na watafiti wengine, idara ya ushauri kwa wakulima na Utawala ili kuhakikisha kuwa ushauri unaotokana na matokeo ya utafiti wa FSR unafuatwa na wakulima. Mawasiliano mazuri zaidi kati ya Wafadhili na Serikali yanahitajika ili kuhakikisha kuwa mshikamano kama huo unafanya kazi.

Kutopokelewa kwa ushauri wa kutumia urea kwenye kilimo cha mpunga kumetoa msukumo kwa watafiti na wakulima kutafuta mbinu zingine za kuboresha rutuba ya majaluba. Majaribio ya kutumia viasili kama vile samadi, pumba za mpunga na miti na mimea jamii ya mikunde badala ya urea yamefanyika. Hata hivyo miti na mimea ya jamii ya mikunde haikufanikiwa sana kutokana na hali ya ukame. Pia nusu ya wakazi wa Usukumani hawana jinsi rahisi ya kupata na kutumua samadi (ambayo nyingi hata hivyo imechujuka kutokana na kutoandaliwa na kutunzwa vyema). Tatizo lingine kubwa katika matumizi ya samadi ni mahitaji makubwa ya nguvu kazi katika kusomba na kusambaza mbolea shambani ambako ni mbali. Suala hilo linakuwa gumu hasa ukizingatia kuwa nguvu kazi iliyopo haswa Shinyanga haitoshelezi mahitaji, na kwamba wakulima hawaoni umuhimu kwa hivi sasa kuwekeza katika ustawishaji wa rutuba ya udongo haswa kwenye mbuga. Utafiti wa karibuni kuhusu balansi ya virutubisho vya mimea kwenye udongo, kwa upande wa Shinyanga haukuonyesha dharura yoyote kuhusu upungufu na hivyo kuunga mkono dhana ya wakulima kuhusu suala hilo. Pamoja na kampeni kubwakubwa za kuhimiza matumizi ya samadi wakati wa Mkoloni na hata juhudi za Serikali, matumizi ya samadi bado ni ya hali ya chini sana katika kanda zote za kilimo. Ni maeneo ya karibu na Mwanza tu ambako samadi na mbolea za viwandani ndizo zinatumika kwa kilimo cha bustani na kwa kidogo kwenye kilimo cha mihogo na mahindi. Hata hivyo, viwango vinavyotumika ni vidogo mno kuweza kupunguza nakisi katika ardhi za kichanga.

Dhana au itikadi za INM na LEISA kwa nchi za kusini mwa jangwa la Sahara zinaonyesha kufanikiwa zaidi pale ambapo kuna mbinyo mkubwa katika matumizi ya ardhi kwa kilimo na mifugo, na upatikanaji wa soko la kutosha na la uhakika. Pia juhudi za nguvu za Serikali katika kusaidia kuimarisha sekta ya kilimo ni takwa lingine la kuwezesha ufanisi wa dhana za INM na LEISA kufanikiwa, na kulinda sekta ya kilimo ya nchi hizo kutokana na ushindani wa nchi zenye viwanda. Dhana hizo za INM na LEISA haziwezi kufanikiwa pasipo kutekelezwa kwa matakwa yaliyotajwa hapo juu. Mifano mbalimbali toka nchi za kusini mwa jangwa la Sahara na Asia inaonyesha kuwa dhana ya kutumia nguvukazi zaidi inaweza kupunguza matunda ya nguvukazi hiyo. Wasambazaji wa sera za LEISA wanaonekana kutojua kuwa dhana hizo zinaweza kuleteleza umaskini katika kaya za wakulima. Kwa wakulima wenye kipato duni njia yoyote ile ya kuboresha kilimo lazima kwanza ilenge maslahi ya kiuchumi na kijamii. Hivyo bila kutumia pembejeo za kutosha kutoka nje kunaweza kudidimiza ustawi wa kilimo, na kwa sababu hiyo LEISA inabidi ianze kushutumu sera za mageuzi zinazoendelea katika nchi hizo.

Wazo kuu la hitimisho ni kuwa dhana za INM na LEISA kwa hivi sasa si sahihi katika kutengeneza mazingira ya kustawisha na kudumisha rutuba katika kilimo cha mpunga Usukumani. Wakulima wenye majaluba kwenye udongo wa mbuga wameridhika na mavuno wanayopata na hawana sababu ya kuwekeza nguvu zao katika matunzo ya ardhi. Hata hivyo kwa wale ambao mashamba yao yako kwenye michanga inabidi wawekeze nguvu kazi katika kuboresha na kudumisha rutuba kama watapenda kuendeleza ustawi wa uzalishaji mpunga kwa kipindi kirefu kijacho. Hali ilivyo hivi sasa haionyeshi dalili za kufanikiwa kwa jambo hili. Kwa upande mwingine mfumuko wa uzalishaji wa mpunga Usukumani ni mfano mzuri wa kuonyesha jinsi wakulima wanavyoweza kufanya mabadiliko ili kukabiliana na mbinyo wa ongezeko la watu, ubora wa uchumi na masoko, na uwezekano kupunguza gharama za uzalishaji kama ilivyo kwenye mbuga. Nakisi katika virutubisho vya mimea udongoni, siyo kigezo pekee cha kuwafanya wakulima watumie mbolea. Ushirikishwaji zaidi wa wakulima haswa katika hatua za awali kupanga miradi inabidi upewe kipaumbele zaidi na miradi ya utafiti inayowashirikisha wakulima (FSRE) ili kuzuia migongano kati ya malengo ya mkulima na watafiti.

Mikakati yoyote ya kustawisha na kuendeleza kilimo cha mpunga Usukumani (pamoja na ile ya INM na LEISA) lazima ijengwe katika misingi ya uchambuzi yakinifu wa mazingira ya mkulima, yaani hali ya hewa na udongo, uchumi, jamii na siasa, pamoja na mahusiano yake. Kwa Usukumani, jambo hili linahitaji kuboreshwa kwa njia za mawasiliano, kuongezeka kwa juhudi za serikali katika kuisaidia sekta ya kilimo, kupunguzwa kwa kodi inayotozwa zao la pamba, kupunguza uingizaji wa mpunga kutoka nje ya nchi, kudhibiti ongezeko kubwa la watu, kubadilisha mfumo wa ufugaji na kupanua upatikanaji wa ajira nje ya sekta ya kilimo. Mseto mzuri wa utunzaji ardhi (INM) kwa hiyo ungekuwa kutumia urea kwenye majaluba na samadi kwenye mashamba ya mihogo/mahindi na pamba yaliyo karibu karibu. Pasipo mazingira bora ya kiuchumi na kisiasa idadi ya watu Usukumani itaongezeka hadi kulazimisha matumizi makubwa zaidi ya nguvukazi katika uzalishaji. Badala ya kuleta mapinduzi ya kimaendeleo katika kilimo kutakuwa na mapinduzi ya kurudisha nyuma au kudumaza kilimo.

Samenvatting

Dit proefschrift onderzoekt mogelijkheden voor duurzame rijstteelt en algemene landbouwontwikkeling in de Mwanza en Shinyanga regio's in het noordwesten van Tanzania, vaak Sukumaland genoemd vanwege de overheersende aanwezigheid van de Wasukuma bevolking. Sukumaland heeft grotendeels een semi-aride klimaat en landbouw wordt belemmerd door onregelmatige en geringe regenval. In de afgelopen vijftig jaar is de bevolkingsdichtheid vrijwel overal verdubbeld. De sterke vermeerdering van de bevolking was de aanzet tot enkele belangrijke veranderingen in de landbouwbedrijfssystemen van deze regio's. Een belangrijke verandering is een afname van graasgebieden in de valleien door een toename van de rijstteelt. De rijstteeltsystemen in Sukumaland doen dienst als een voorbeeldstudie voor het onderzoek naar het belang van sociale, economische en biofysische indicatoren op het veld, boerderij, stroomgebied en regionaal/nationaal niveau in de ontwikkeling van duurzame landbouw. Het onderzoek concentreert zich op het beheer van de bodemvruchtbaarheid in plaats van efficiënt waterverbruik of vatbaarheid voor plagen en ziektes vanwege het huidige grotere belang ervan voor duurzame rijstteelt in Sukumaland.

Economische herstelprogramma's, bekend als structurele aanpassingsprogramma's, zijn in Tanzania begonnen rond 1986 en werden begeleid door het Internationaal Monetair Fonds (IMF) en de Wereld Bank. Deze programma's vereisten drastische wijzigingen in het nationaal economisch beleid van Tanzania en hadden grote invloed op de in- en verkoop van landbouwproducten. Geliberaliseerde markten en particuliere handelaren worden geacht de landbouwsector te verbeteren via een zeer gewenste intensivering van de landbouw door verhoogde consumpties van kunstmest, onkruidbestrijdingsmiddelen en pesticiden. De zogenaamde liberalisering van de internationale landbouwhandel gaf echter ontwikkelingslanden als Tanzania slechts een geringe, verhoogde toegang tot de markten van de geïndustrialiseerde landen, en beperkte nauwelijks het dumpen van landbouwproducten door de geïndustrialiseerde landen. Boeren in ontwikkelingslanden kunnen niet concurreren met boeren in geïndustrialiseerde landen. Dit gebrek aan verkoopmogelijkheden in combinatie met de lage koopkracht van consumenten in ontwikkelingslanden en lage landbouwprijzen vormt een ernstige belemmering voor de voedselzekerheid in ontwikkelingslanden. Specifieke gegevens voor Tanzania laten zien dat in dit land de voedselproductie per hoofd van de bevolking toenam tussen 1970 en 1980, gelijk bleef in de periode 1980-1990 en begon af te nemen na 1990. Vanuit nationaal oogpunt is dit duidelijk geen duurzame landbouwontwikkeling.

Men denkt dat het geleidelijke proces van uitputting van bodemnutriënten in veel gebieden van Afrika bezuiden de Sahara een nogal verborgen reden is voor de trage landbouwgroei in vergelijking tot de hoge bevolkingsgroei. Een "Integrated Nutrient Management" (INM) strategie, die het gebruik van lokaal aanwezige hulpbronnen combineert met externe invoeren, en verder beheerspraktijken omvat die nutriëntenverlies uit het systeem tegengaan, en interventies die nutriënten aanvullen van buitenaf, wordt aanbevolen om de productie te verhogen en duurzame landbouw te ontwikkelen in Afrika bezuiden de Sahara. INM methodes zijn een van de belangrijke strategieën in de "Low External Input and Sustainable Agriculture"

(LEISA) benadering. LEISA strategieën streven een optimaal gebruik na van lokaal aanwezige hulpbronnen en slechts een beperkt gebruik van externe invoeren op de meest efficiënte wijze. Voor het beheer van de bodemvruchtbaarheid dienen lage giften van kunstmest gecombineerd te worden met toedieningen van koeienmest en indien van toepassing het gebruik van groenbemesting, compost, het aanplanten van bomen en struiken en erosiebestrijding. Het resultaat behoort een duurzame verhoogde productie te zijn.

De centrale vraag in dit proefschrift is of INM en LEISA bruikbaar zijn voor boerenhuishoudens in de rijstteeltsystemen van Sukumaland onder de huidige economische omstandigheden zoals voortgebracht door de structurele aanpassingsprogramma's. De ruimere vraag in dit proefschrift is of boerenhuishoudens in landen bezuiden de Sahara INM/LEISA kunnen gebruiken voor de ontwikkeling van duurzame landbouw tegen de achtergrond van liberalisering van de internationale landbouwhandel, structurele aanpassingsprogramma's en hevige bevolkingsgroei. Op veel plaatsen binnen Sukumaland zijn cassave, maïs of sorghum als voedselgewas belangrijker dan rijst, terwijl katoen, maïs of tuinbouwgewassen belangrijker kunnen zijn als handelsgewas. Duurzame landbouwontwikkeling in Sukumaland, en elders, hangt af van alle aanwezige teeltsystemen en van de wisselwerkingen van deze teeltsystemen met veeteelt en andere deelsystemen op boerderij niveau.

De prestaties in de voedsel- en handelsgewassen sectoren van Tanzania en de beschikbaarheid en consumptie van landbouwinputs gedurende 1986-96 worden vergeleken met periodes vóór de door IMF/Wereld Bank gesteunde hervormingen. De positieve ontwikkelingen in de eerste vijf jaren van de hervormingen blijken niet aan te houden. Productiviteit niveaus per hoofd van de bevolking voor belangrijke voedsel- en handelsgewassen zijn nu aan het afnemen. Flinke prijsstijgingen voor kunstmest en beschikbaarheidsproblemen van inputs in de dorpen staan in verband met de liberalisering van de voorziening en prijsbepaling van landbouwinputs. De verwijdering van subsidies op landbouwinputs vanaf 1991 is erg belangrijk om het verval van de maïsproductie, het belangrijkste voedselgewas in Tanzania, te verklaren. Structurele aanpassingsprogramma's gaan doorgaans te ver in het verminderen van de rol van de overheid. Een gepaste inbreng van de overheid is echter misschien nodig voor het waarborgen van een hogere consumptie van landbouwinputs en dus van een betere productiviteit van de landbouwsector in Tanzania.

Een beschrijving van de dynamiek in de landbouwbedrijfssystemen van Sukumaland in de afgelopen honderd jaar laat zien dat Sukumaland mensen aantrok vanwege de geringe aanwezigheid van ziektes voor mensen en dieren. De landbouw werd in het begin alleen op de zandige, hoger gelegen gedeeltes van de hellingen bedreven omdat deze makkelijk met de hak bewerkt kunnen worden. Stijgingen in de bevolkingsdichtheid veroorzaakten uitbreidingen van boerderijen in de richting van de lager gelegen gedeeltes van de hellingen. De graasgebieden voor het vee werden verkleind door de teelt van rijst in de laagste gedeeltes van de hellingen. Boerenfamilies met grote kuddes verhuisden naar nieuwe gebieden zonder tseetseevlieg en konden grote boerderijen hebben door de beschikbaarheid van ploegen en ossen. Tussen 1950 en 1970 steeg het inkomen van boerenfamilies sterk in Sukumaland vanwege de extensieve, financieel lucratieve teelt van katoen. Tussen 1970 en 1990 werd de katoenteelt veel minder winstgevend en dit leidde tot een diversiteit van handelsgewassen bepaald door agroecologische verschillen en afstand tot Mwanza stad. Verdergaande stijgingen van de bevolkingsdichtheid veroorzaakten een daling in bouwland en stuks vee per hoofd van de bevolking, en verschuivingen in gewassenteelt. Gangbare gewassen als sorghum en pluimgierst werden vervangen door minder intensieve (cassave) en meer productieve (rijst, maïs, cassave, zoete aardappelen) gewassen. Deze ontwikkelingen waren niet overal hetzelfde in de Mwanza en Shinyanga regio's vanwege verschillen in bevolkingsdichtheid en agroecologische omstandigheden. Tegenwoordig zijn er tekenen van landbouwintensivering nabij Mwanza stad terwijl extensieve landbouw overheerst in de overige gedeeltes van Sukumaland.

Recente landbouwkundige studies van Sukumaland hebben de aandacht gevestigd op het belang van regenafhankelijk, laagland rijst in de bestudeerde landbouwbedrijfssystemen. Meer dan een derde van de rijst geproduceerd in Tanzania is afkomstig uit Sukumaland. Boeren verhoogden hun rijstproductie snel toen de rijstteelt winstgevender werd dan katoen en andere gewassen, en rijst populairder werd als voedselgewas omdat het grote hoeveelheden calorieën kan produceren op kleine stukjes land. De sterke stijging van de rijstteelt in de afgelopen 25 jaar is verbazingwekkend gezien de geringe en zeer onbetrouwbare regenval in Sukumaland. Boeren ontwikkelden zeer productieve regenafhankelijke, laagland rijstsystemen enkel op basis van hun kennis van bodems, regenval patronen en topografie, en van hun experimenten met waterbeheer systemen, variëteiten, en methoden voor planten en bewerken van het land. Rijstteeltmaatregelen volgen nauwkeurig verschillen in ecologie en boerenfamilie kenmerken. Rijstvariëteiten worden grotendeels gekozen op basis van de wateromstandigheden in het veld. De rijstteelt is intensiever in de Mwanza regio waar men overplant, terwijl breedwerpig zaaien overheerst op de grotere velden in de Shinyanga regio. Boerenfamilies telen rijst voor voedsel en geld, maar voornamelijk voor voedsel in Mwanza en voornamelijk voor geld in Shinyanga. Water en onkruiden zijn de belangrijkste belemmeringen in de productie, maar geringe bodemvruchtbaarheid is ook een probleem op de zandige gronden in de Mwanza regio. Opbrengsten zijn omlaag gegaan vanwege een onafgebroken teelt zonder noemenswaardige toedieningen van organische meststoffen of kunstmest. De opbrengsten op de meer kleiachtige rijstvelden in de Shinyanga regio zijn echter nog steeds voldoende door de relatief korte periode (10-20 jaar) van rijstverbouw. Echter, een keer in de drie jaar slagen boeren er niet in om voedsel en geld te verkrijgen uit rijstverbouw vanwege onvoldoende, te late of te onbetrouwbare regenval.

Bodemvruchtbaarheid onderzoek, volgens een "Farming Systems Research/Extension" (FSRE) methode, tussen 1990 en 1996 op rijstvelden van boeren in Sukumaland, was een reactie op klachten van boeren over teruglopende rijstopbrengsten. Men dacht dat deze daling te wijten was aan een vermindering van de bodemvruchtbaarheid. Het onderzoek toonde aan dat het breedwerpig toedienen van 30 kg N ha^{-1} in de vorm van ureum in natte rijstvelden op het moment van uitschieten de rijst graanopbrengsten verhoogde met 500-900 kg ha^{-1} in bijna elk type rijstveld van Sukumaland. Toedieningen van meer dan 30 kg N ha^{-1} waren minder winstgevend met de gewas- en kunstmestprijzen van 1996. Het effect van ureum op de rijstopbrengst was beter bij toediening tijdens het maximale stadium van uitstoelen, en wanneer het waterpeil in de rijstvelden bij het toedienen minder dan 15 cm was, en wanneer de velden erg zanderig waren. De relatief kleine verschillen in effect per veld (omgeving) in alle seizoenen gaven geen aanleiding tot veelsoortige voorlichtingsboodschappen. Een toediening in een keer van 30 kg N ha^{-1} in de vorm van ureum tijdens het uitstoelen van rijst wordt aldus aanbevolen voor geheel Sukumaland.

Ondanks de relatief hoge, gemiddelde productiviteit index voor de geringe toediening van ureum in rijst was er vrijwel geen adoptie door boeren. De belangrijkste redenen hiervoor waren problemen met de beschikbaarheid van ureum in de dorpen en een afnemende winstgevendheid van de rijst-ureum technologie ten gevolge van de door de IMF/Wereld Bank aangespoorde hervormingsmaatregelen. Andere redenen waren de geringe noodzaak om ureum te gebruiken op meer kleiachtige rijstvelden; de matige betrokkenheid van de voorlichtingsdienst; de verwarrende onderzoeksberichten aangaande bodem vruchtbaarheidsbeheer in rijst; de hoge mate van onzekerheid in de landbouwbedrijfssystemen van Sukumaland; en de geringe participatie van boeren tijdens het vaststellen van prioriteiten in de activiteiten op boerenvelden. De FSRE methodiek heeft stevig verankerde banden nodig met de voorlichtingsdienst, het gangbare onderzoek en beleidsmakers voor een effectieve adoptie van landbouwkundige methoden. Een betere coördinatie van activiteiten tussen donoren en regeringen is een essentiële voorwaarde voor het laten functioneren van dit soort banden.

De mislukte adoptie van ureum in rijst spoorde onderzoekers en boeren aan om te zoeken naar alternatieven voor het verbeteren van de bodemvruchtbaarheid in rijstvelden. Er werd onderzoek gedaan naar het gebruik van lokaal aanwezige hulpbronnen zoals koeienmest en rijst kaf, en de introductie van groenbemesting en multifunctionele bomen als een alternatief voor ureum. De resultaten van groenbemesting en multifunctionele bomen vielen tegen vanwege een beperkte biomassa productie die werd veroorzaakt door het semi-aride klimaat. De helft van de boerenfamilies in Sukumaland heeft geen eenvoudige toegang tot koeienmest, en de kwaliteit van deze mest is verder laag vanwege het bewaren in de open lucht en de zeer geringe toevoegingen van gewasresten. Een ernstig probleem is ook de relatief grote hoeveelheid arbeid die gemoeid is met het transporteren en onderploegen van volumineuze, organische materialen zoals koeienmest, groenbemestingsgewassen, rijst kaf en bladeren van bomen in de relatief afgelegen en minder toegankelijke rijstvelden. De benodigde arbeidstoename per hectare is moeilijk haalbaar in de dunbevolkte Shinyanga regio, en verder ongewenst voor boerenfamilies overal in Sukumaland vanwege de te verwachte daling in arbeidsproductiviteit. Afgezien daarvan zien boeren met kleiachtige rijstvelden geen noodzaak om dusdanig veel te investeren in het beheer van bodemvruchtbaarheid. Een nutriëntenbalans berekening voor de regenafhankelijke, laagland rijstteeltsystemen in Sukumaland leverde geen ernstige uitputtingscijfers voor de belangrijkste nutriënten op en dit is in overeenkomst met de houding van de boeren. Ondanks indrukwekkende promotiecampagnes voor het gebruik van organische meststoffen in Sukumaland tijdens de koloniale periode en recente pogingen van de Tanzaniaanse overheid, is er nog steeds een zeer geringe adoptie in vrijwel alle teeltsystemen. Alleen dichtbij Mwanza stad gebruiken boeren koeienmest in tuinbouwveldjes en, op kleinere schaal, in maïs/cassave velden. De toegediende hoeveelheden zijn echter onvoldoende om positieve nutriëntenbalansen te bewerkstelligen op deze hoger gelegen, zandige bodems.

INM/LEISA successen in SSA blijken gekenmerkt te worden door een relatief hoge intensiteit in het landgebruik, hoge bevolkingsdichtheid, gemiddeld tot hoge vee dichtheid, goede toegang tot de markt en nabijheid van grote, stedelijke markten (tuinbouw). Een actieve steun van SSA-regeringen voor hun landbouwsectors is verder nodig om duurzame landbouw te verkrijgen via INM/LEISA benaderingen en om hun landbouwsectors te beschermen tegen competitie uit de geïndustrialiseerde landen. INM/LEISA benaderingen zijn niet geschikt voor landbouwbedrijfssystemen in SSA die deze kenmerken missen. Verschillende voorbeelden uit SSA en Azië tonen dat een vergaande afhankelijkheid van arbeidsintensieve methoden kan leiden tot een afnemende arbeidsproductiviteit. LEISA voorstanders schijnen zich er in hoge mate niet bewust van te zijn dat landbouwmethoden, voornamelijk gebaseerd op arbeidsintensieve technieken, kunnen leiden tot verarming van boerenfamilies. Voor kleinschalige boeren moet duurzame landbouw in de eerste plaats sociaal-economisch levensvatbaar zijn. Onvoldoende gebruik van externe inputs kan LEISA veranderen in een niet duurzame vorm van landbouw en daarom moeten LEISA voorstanders beginnen met het bekritiseren van de structurele aanpassingsprogramma's in SSA.

De belangrijkste conclusie is dat INM/LEISA benaderingen op dit moment niet geschikt zijn voor het bewerkstelligen van duurzaam bodem vruchtbaarheidbeheer in de rijstteeltsystemen van Sukumaland. Boeren met rijstvelden gelegen op vruchtbare kleigronden zijn nog steeds tevreden met de graanopbrengsten, en zijn nog niet gemotiveerd om arbeid en geld te investeren in bodem vruchtbaarheidbeheer. Vooral op meer zandige rijstvelden zullen boeren echter voor duurzame rijstteelt in de toekomst flink moeten investeren in bodem vruchtbaarheidbeheer. De huidige situatie in Sukumaland maakt zulke investeringen hoogst onwaarschijnlijk. De reusachtige toename van de rijstteelt in Sukumaland is aan de andere kant een goed voorbeeld van de aanpassing van boeren aan een toenemende bevolkingsdichtheid, veranderingen in marktmogelijkheden, en gunstige bodem vruchtbaarheid omstandigheden in de valleien. Negatieve nutriëntenbalansen rechtvaardigen verder niet altijd adviezen aan boeren voor het direct aanwenden van kunstmest en/of organische meststoffen. Meer participatie van boeren, vooral tijdens het bepalen van prioriteiten, is ook nodig in FSRE programma's om het verkeerd inschatten van boerendoelstellingen te voorkomen.

Elke strategie voor duurzame rijstteelt en landbouw in de toekomst van Sukumaland, INM of LEISA inbegrepen, dient gebaseerd te zijn op een grondige analyse van biofysische, sociaal-economische en overheidspolitieke factoren en hun verbindingen. Zo'n strategie heeft een gunstige economische en politieke omgeving nodig. In Sukumaland vereist dit een verbetering in de infrastructuur, een verhoogde steun van de overheid aan de landbouw, een afname in het belasten van de katoensector, een verminderd vertrouwen op rijstimporten, een hogere bevolkingsdichtheid, intensieve veeteelt en een ruimer aanbod van werkgelegenheid buiten de landbouw. Een goede INM strategie in Sukumaland zou dan zijn om ureum te gebruiken in rijst en koeienmest in de dichtbij zijnde cassave/maïs en katoen velden. Zonder een gunstige economische en politieke omgeving zal de bevolkingsgroei in Sukumaland leiden tot een voornamelijk op arbeid gebaseerde intensivering. In plaats van een evolutie in de landbouw zal er sprake zijn van een aftakeling in de landbouw.

About the author

Hubertus Catharina Christiaan Meertens was born in 1960 in Maastricht, The Netherlands. He received his secondary education at the "Sint Maartens College" in Maastricht and obtained his Gymnasium-ß certificate in 1979. In the same year he started his studies in Tropical Crop Science at Wageningen Agricultural University, The Netherlands. From May 1986 to November 1987 he was coordinator of agricultural technical advice at the Agromisa Foundation, an NGO in Wageningen. This work was done as an alternative to military service. During his studies he spent further half a year in Kenya. In 1988 he obtained his MSc degree from Wageningen Agricultural University with a major in Tropical Crop Science and minors in Extension Education, Tropical Animal Production and Rural Sociology of the Tropics and Subtropics.

From 1989 to 1992 he was employed by the Netherlands Development Organization (SNV) as agronomist/extensionist in the Tanzania/Netherlands Farming Systems Research Project Lake Zone. During that period he was based at Maswa town in the Shinyanga region of Tanzania. Back in the Netherlands he was employed as a scientific staff member by the Royal Tropical Institute (KIT) at Amsterdam, The Netherlands, from November 1992 until the end of April 1993. The result of this work was a booklet on farming systems dynamics in Sukumaland, Tanzania, which was published by KIT Press in 1995. From 1994 to 1996 he was employed by FAO as an Associate Professional Officer in fertilizer use and plant nutrition in the Kilimo/FAO Plant Nutrition Programme in Tanzania. During that period he was based at Mwanza town in the Mwanza region of Tanzania. From May 1997 onwards he started working on the present dissertation. In September 1998 and January 1999 the thesis writing was twice interrupted for short-term consultancies to Tanzania. These consultancies were both done in the framework of the Tanzanian Agricultural Sector Management Project, financed by the World Bank.