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The prospects for integrated nutrient management for sustainable rainfed lowland rice production in Sukumaland, Tanzania

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Abstract

The possibilities of integrated nutrient management for sustainable rice cultivation are investigated for rainfed, lowland rice in Sukumaland, northwestern Tanzania. Typical, hardpan rice soils in Sukumaland have rather low levels of organic matter, total nitrogen and available phosphorus, and a low to medium amount of exchangeable potassium. Consumption of mineral fertilizers in rice is, however, 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 without increases in capital inputs 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. Using rice straw as cattle feed and thatching material has priority over soil fertility improvement. Some farmers indicate that at present there is not yet an urgent need for improved integrated nutrient management in Sukumaland rice cultivation. Adoption of integrated nutrient management based technologies depends on conducive socio-economic, agro-ecological and public policy circumstances. Farmer investment in learning and a favourable policy environment are thus no guarantee for worldwide adoption of these technologies by farm households.

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 made donors and development agencies 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) (Smaling et al. 1996). The efficient combination of these methods is called Integrated Nutrient Management

(INM). Pretty (1995) presents some successful examples of INM systems in developing countries but admits that these are still isolated instances. Pretty (1995) argues that farmers must invest in learning because adoption of INM requires increased inputs of labour, management skills and knowledge. However, Pretty (1995) regards the absence of a favourable policy environment as the principal barrier to INM and LEISA in general because 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) argued that the state should withdraw from intervention in the economy and open up all economic activity, especially in agriculture, to market forces. Further 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. In the mid-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 parts of Sukumaland for its contribution of food and cash to the households (Meertens et al. 1999). 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 farmgate price increases of urea. 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 research in that direction in Sukumaland rice. Labour productivity is investigated in detail because the relatively high labour requirements of many proposed methods involving locally available resources appear to be a serious constraint for adoption by households. The aim of this paper is to use the Sukumaland case study for drawing more general conclusions with regard to the adoption potential of INM systems and to show that farmer investment in learning and a favourable policy environment alone can not guarantee adoption of INM based technologies.

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).

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 in Sukumaland is very important in the broad valleys with dominant hardpan soils (Solodic Planosols) which receive more than 800 mm average annual rainfall (Meertens et al. 1999). Analysis of composite soil samples, taken at the end of the season to a depth of 0–20 cm from typical, hardpan rice soils in Sukumaland, revealed a low amount of organic carbon (12.4 g kg^{-1}), a very low amount of total nitrogen (0.9 g kg^{-1}), a low amount of available phosphorus (2.9 mg kg^{-1} P-Bray), and a low to medium amount (0.25 meq 100 g^{-1}) of exchangeable potassium (Meertens et al. 1992).

To catch and control the uncertain water supply farmers construct bunds around the rice fields in which runoff water accumulates. The water holding capacity of the rice soils is very good due to the presence of a 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 (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 some parts of Mwanza region with more sandy rice fields, low soil fertility is also regarded as a main constraint to rice production. Incorporation of weeds is, however, the only soil amendment made by farmers. The use of agricultural inputs is very low. 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 (Meertens et al. 1999).

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, an agricultural research substation. 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 rice yield by 1419 kg ha^{-1} relative to the control yield of 4846 kg ha^{-1}. The puddling in of 10 tons cassia shoots ha^{-1} increased rice 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 (Doggett 1965).

In the 1960s, 1970s and 1980s there was no further research on the use of locally available resources for soil fertility improvement in Sukumaland rice due to the availability of relatively inexpensive mineral fertilizers. The complete withdrawal of subsidies on mineral fertilizers in Tanzania during the early 1990s gave, however, a new impulse to such type of investigations. Examples are research on 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 rice yield by 580 kg ha^{-1} relative to the control yield of 2438 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. Green manuring increased rice yield by 1600–2000 kg ha^{-1} relative to the control yield of 2433 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.

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 after only 8–9 weeks of growth a total dry matter yield of about 10 tonnes ha^{-1} (equal to about 50 tonnes fresh green matter ha^{-1}). 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 by 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 rice yield by 900–1000 kg ha^{-1} relative to the control yield of 2580 kg ha^{-1} (Makoye and Winge (1996) and J.J. Makoye, personal communication). 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 about 3.6 tonnes of farmyard manure is potentially available per year for each household with an average cultivated area of about 2.5 ha (Meertens and Lupeja 1996). This is only enough to supply a dose of 10 tonnes ha^{-1} on 0.36 ha of rice 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 (Kundu and Ladha 1999). 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 nitrogen to the soil after the first year.

Ravnborg (1990) states that 70% of the households in a densely populated area near 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). A survey in Maswa district, Shinyanga region, showed that only 2% of all households applied kraal manure to their rainfed lowland rice fields. This survey revealed further 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

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 inexpensive 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).

Other labour intensive methods for improving soil fertility like deep placement of urea fertilizers, application of farmyard manure or incorporating rice straw are also not widely used by rainfed lowland rice farmers (Kundu and Ladha 1999). Households are not eager to increase their inputs of labour per farm and per field. Deep placement of urea fertilizers in heavy-textured soils is more efficient than broadcasting urea into the floodwater but this last practice is still widely followed by many Asian rice farming households. 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 (Mohanty et al. 1999). 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 (Mutert 1995).

Apart from the labour intensity the incorporation of rice straw has additional problems. 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. An example from Sri Lanka shows that 20 kg urea ha^{-1} is needed for this (Mulleriyawa and Wettasinha 1997). In Sukumaland the incorporation of rice straw in 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. Due to insufficient grazing areas in Sukumaland crop residues in the field like rice straw have become important additional livestock feeding.

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. 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

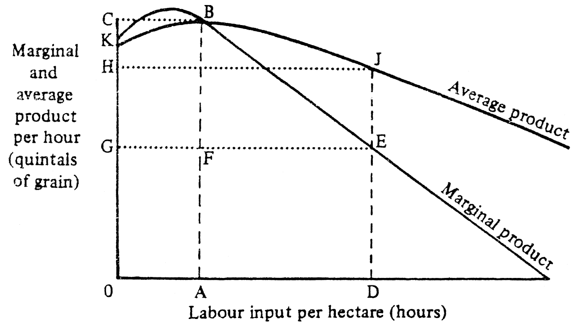

Figure 1. Returns to labour under different intensities of land use. Source: Upton (1996).

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 1 shows, however, that high labour inputs per hectare without increases in capital inputs lead to lower marginal and average products per hour of labour. The average product per hour, that is the total product divided by the 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 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).

Intensive labour use in agriculture on Ukara island

A good example of intensified labour use in agriculture due to population pressure and land shortage is supplied by Ukara, a small island in 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).

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 ha in 1965) every 2–3 years (Ludwig 1968). The farmyard manure is transported to the fields in baskets carried on the heads. The INM methods performed by the Wakara such as 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 1). Table 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.

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. During a

Table 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).

visit to Ukara island in 1995 by the Kilimo/FAO Plant Nutrition Programme in Mwanza region we observed 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 principally 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). Despite having been extension messages for over fifty years, almost all these 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 rely too much on 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 good 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.

Discussion and conclusions

This paper shows that the prospects for integrated nutrient management in Sukumaland rice cultivation are not positive due to labour constraints at the farm household level, the semi-arid nature of the environment and problems concerning the availability of organic and mineral fertilizers.

The 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 without increases in capital inputs cause a decrease in the productivity of labour. Only serious land shortages due to high population densities will force farm households to accept a decrease in the productivity of labour (Boserup 1965). Population pressure and land shortage are apparently not yet serious enough in the case of Sukumaland rice cultivation. Farmers in some parts of Sukumaland even state that their rice fields are still fertile. Their strategy is to have relatively low rice yields (2300 kg ha^{-1}) on large rice fields.

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 Sukumaland rice cultivation will have limited impact on the soil fertility situation due to insufficient biomass production in the three months before rice transplanting available.

Availability of organic fertilizers is restricted in Sukumaland. In fact there is not enough cattle manure available for maintaining soil fertility in Sukumaland. Half of the households do not own livestock and therefore have no easy access to cattle manure. Farm households in Sukumaland are not eager to incorporate rice straw in the rice soils due to the alternative uses of rice straw as cattle feed and thatching material. Shapiro and Sanders (1998) mention that most crop residues in semi-arid West Africa are also removed for uses with higher economic value (feed, fuel, building materials) than soil fertility improvement. The access to mineral fertilizers is very low due to sharply increased prices and serious availability problems. This makes the integrated use of organic and mineral fertilizers rather impossible in Sukumaland.

This paper has shown that there can be serious blocks to the use of locally available resources for soil fertility improvement even when there is a favourable policy environment for INM technologies. The limited success of INM resembling soil fertility enhancing technologies in semi-arid West Africa after many years of promotion (Enyong et al. 1999) shows that adoption of INM is not only a complex issue in Sukumaland. Pingali et al. (1987) found that in SSA organic fertilizers and so INM technologies are mainly used in farming systems with high landuse intensity often characterised by a high population density and/or good market access. Agricultural success in such circumstances appears to be a combination of favourable environments, promising locations, supportive infrastructure and conducive government policies (Hyden et al. 1993). So the adoption of INM depends on a wide range of factors. Programmes and projects dealing with the promotion of INM technologies in certain areas should investigate if these areas are at present suitable for the introduction of such technologies. This will lead to less failures in the adoption of INM technologies than merely advocating farmer investment in learning and a favourable policy environment.

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