Managing Africa's Soils No. 12

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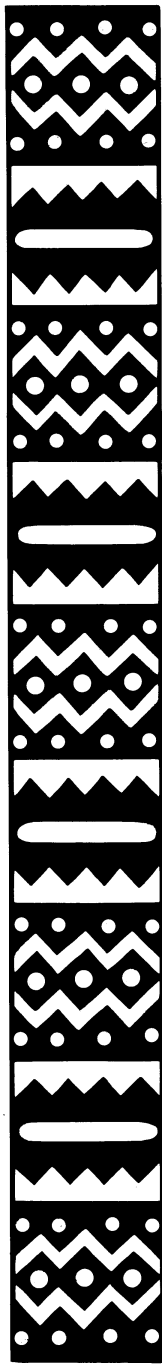

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About NUTNET

NUTNET stands for *Networking on soil fertility management: improving soil fertility in Africa – Nutrient networks & stakeholder perceptions*. It is a partnership of fifteen organisations that come from six African and two European countries: INERA, Burkina Faso; SOS Sahel, Ethiopia; KARI, KIOF & ETC East Africa, from Kenya; IER, Mali; Environment Alert & Makerere University, from Uganda; IES, Zimbabwe; IIED & IDS from the United Kingdom; and AB/DLO, LEI/DLO, SC/DLO, ETC & KIT, from The Netherlands. NUTNET was conceived with the primary aim of bringing together the three following research programmes:

- *The dynamics of soil fertility management in savannah Africa*, co-ordinated by IIED and IDS/UK;
- *Spatial and temporal variation of soil nutrient stocks and management in sub-Saharan Africa systems* (VARINUTS), co-ordinated by SC/DLO in The Netherlands;
- *Potentials of low-external input and sustainable agriculture to attain productive and sustainable land use in Kenya and Uganda* (LEINUTS), co-ordinated by LEI/DLO in The Netherlands.

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Summary

The Office du Niger (ON) is one of the largest irrigation schemes in Sub-Saharan Africa. It was set up in 1932, and since a major overhaul in the 1980s made it possible to regulate water levels more effectively, the scheme has provided a much improved source of income for rice farmers. They could cultivate more intensively, and began transplanting rice, trying new high-yield varieties and using more mineral fertiliser. The economics of rice farming was also improved by the restructuring of the irrigation scheme's management, the liberalisation of the rice market, the privatisation of service delivery, and the devaluation of the CFA franc in 1994. The irrigation scheme now attracts many settlers and temporary labourers.

Rice farmers in the ON are aware of the importance of maintaining soil fertility, and they keep to (and sometimes even exceed) the recommended dose for mineral fertiliser, unlike their counterparts cultivating millet in the neighbouring drylands. However, the use of organic fertiliser on rice is limited and erratic. Partial nutrient balances for rice are positive for nitrogen and phosphorus but negative for potassium, because most of the rice stubble is consumed by livestock. However, the soil's nutrient stocks still compensate for the potassium losses, and farmers can also use new types of fertiliser that contain extra potassium and microelements. There is some debate about the extent to which rice farmers are affected by soil degradation and problems with salinity and alkalinity. Some parts of the ON have had problems with rice production that may be linked to soil degradation, but the continuous high rice yields suggest that the overall situation is good.

Production in the ON has recently diversified, and farmers have started supplementing their income by growing vegetables on the rice fields in the dry season. They rotate the vegetable plots around relatively infertile patches of land, which benefit from the large amounts of manure applied to the vegetables, and subsequently produce better rice yields.

The irrigation scheme has also had an impact on the surrounding drylands. It influences watercourses and wetlands, and people living in the scheme use large amounts of woodland products such as fodder, fuel and construction wood. The rice farmers use draught oxen, and invest their profits in cattle, which are generally tended by Fulani

pastoralists. In the dry season these herds browse rice stubble, and in the wet season they graze areas outside the scheme.

The scheme is currently being expanded, which should improve rural people's livelihoods. However, this could have negative environmental consequences, as it will reduce the available dryland grazing areas and woodlands and increase pressure on the remaining resources, which may lead to conflict over their use. Some of the pressure on resources could be reduced if the rice farmers changed their livestock management practices, and tried to integrate their livestock and cropping systems better.

French summary

Dynamique de la riziculture irriguée au Mali

Depuis le début des années 1990, la riziculture pratiquée dans le périmètre irrigué de *l'Office du Niger* est devenue une réelle source de revenus pour les agriculteurs de la région. Cela est dû en grande partie à la réhabilitation du périmètre irrigué, dans les années 1980, qui a amélioré la maîtrise de l'eau. En conséquence, les agriculteurs ont adopté des méthodes de culture plus intensives telles que le repiquage du riz, de nouvelles variétés à haut rendement et ils ont augmenté les taux d'application d'engrais minéraux. La rentabilité de la riziculture a encore été améliorée par une restructuration à la direction de *l'Office du Niger*, la libéralisation du commerce du riz et, en 1994, la dévaluation du franc CFA.

Les producteurs de riz appliquent les doses recommandées d'engrais minéraux et parfois même plus. C'est une grande différence par rapport aux pratiques habituelles de la culture de mil dans les zones semi-arides environnantes. L'emploi d'engrais organiques pour le riz est, toutefois, limité et erratique. Le bilan des éléments nutritifs pour le riz est positif pour l'azote et le phosphore mais négatif pour le potassium, du fait que les troupeaux de passage en broutent la chaume. Les pertes de potassium sont compensées par les réserves encore présentes dans le sol. Par ailleurs, de nouvelles formules d'engrais apparaissent maintenant sur le marché avec davantage de potassium et des oligoéléments. Il reste à voir dans quelle mesure *l'Office du Niger* a des problèmes de dégradation des sols, de salinité et d'alcalinité. Il semble y avoir des difficultés de production dans certaines parties du périmètre irrigué mais la situation générale est satisfaisante comme le prouvent les rendements élevés de riz.

La culture de légumes dans les rizières durant la saison sèche constitue une autre source de revenus, notamment pour certains membres de la famille tels que les femmes et les jeunes hommes. Les légumes sont cultivés avec de fortes applications de fumier, un système de plus en plus utilisé par les producteurs de riz pour améliorer indirectement la qualité des sols.

L'Office du Niger laisse sa marque sur les zones semi-arides environnantes. Il a influencé la disponibilité des pâturages durant la saison sèche et ses habitants font une utilisation intensive des produits de la brousse tels que fourrage, bois de feu et de construction. Les producteurs de riz qui préparent la terre avec des bœufs ont investi leurs bénéfices dans du bétail, la plupart élevé par les pasteurs Fulani. A la saison sèche, ces troupeaux pâturent sur le chaume de riz et, à la saison des pluies, aux pâturages dans les zones semi-arides.

Le périmètre irrigué est en cours d'expansion. Cela améliorera les conditions de vie de la population rurale, certes, mais pourrait avoir des conséquences sur l'environnement. L'expansion réduira la superficie des pâturages et des zones boisées, ce qui risque d'accroître la pression sur les ressources naturelles restantes et de créer des conflits vis-à-vis de leur utilisation. Ces pressions peuvent être réduites en changeant les pratiques d'élevage des producteurs de riz, ce qui pourrait conduire aussi à une meilleure intégration du bétail aux principaux systèmes agricoles appliqués dans l'Office du Niger.

1 Introduction

The Office du Niger in Mali is regarded as one of the rare success stories of irrigated farming in West Africa, and it is therefore worth exploring its history and development. This working paper describes the dynamics of rice production in the Office du Niger, and then focuses on soil fertility management and the environmental effects on the surrounding area. It takes a more detailed look at cropping systems, partial nutrient budgets and the economy of rice and vegetable farming in the village of Tissana, and closes with a discussion of the long-term sustainability of the system.

Methodology

In 1995 a multidisciplinary team of researchers set up an action-research programme in the village of Tissana, as part of a larger research programme that covered other agro-ecological zones and cropping systems (cf. Defoer et al., 1997, 1998). The research approach was participatory, and began with a diagnostic exercise in which farmers mapped out the soils and natural resources within the village territory. The next step was to analyse the different fertility management techniques used in the village, and farmers were asked to classify every household according to how many of these techniques were used. In the third phase, farm maps drawn up by selected farmers were used to analyse soil fertility management practices. These maps were also used to identify and quantify the various flows of nutrient inputs and outputs, which enabled researchers to calculate partial nutrient balances. The results of these exercises were discussed with farmers at village meetings, and participants suggested how soil fertility management could be improved for each category of farm. The proposed activities were subsequently planned and implemented.

In addition to spending three years monitoring nutrient flows on 20 farms in Tissana, researchers studied the evolution of soil fertility management practices in this village (Macinanké et al., 1998). They have also been monitoring the economy of rice and vegetable cultivation in the scheme, and consulted published sources for other information about the history of the Office du Niger.

2 The Office du Niger

Location

The Office du Niger (ON) irrigation scheme is located in the Segou region of central Mali, a landlocked country in West Africa that is largely taken up by the Sahara desert (Figure1). The country's total population amounts to about 10 million people. Much of the economy of the Segou region is supported by agriculture, which is based on irrigated agriculture, dryland farming and pastoralism. Dryland farmers in the central region of Segou cultivate millet and legumes, while those in the south grow cotton in rotation with cereals.

Average annual rainfall ranges from 150 mm in the north of the Segou region to 750 mm in the south, although levels vary considerably from year to year. Rainfall in the Office du Niger area ranges from 450-600 mm per year. The rainy season lasts for three to five months, and the dry season is divided into a cool and a hot period. The two growing seasons overlap, with the main rice season falling between May and December, and dry season production of vegetables or rice between November and June.

The soils in this predominantly flat region are composed of "an extensive plain with light sand and gravel soils. Fossilised river valleys, former branches of the Niger, cross the region providing long stretches of clay along the ancient riverbeds. Moving towards the north, soils become progressively sandier as one enters a region of ancient dunes" (Toulmin, 1992:41). The major soil types found in the Office du Niger are sandy (*Seno*), lime (*Danga*) and clay soils (*Moursi* and *Dian*), and their mosaic distribution results in significant spatial variability. The sandy soils are of alluvial origin and not very developed. The sandy and lime soils are poor in organic matter and minerals and may develop sodic characteristics, which prevent crops from growing well. The clay soils show vertisols characteristics, contain numerous calcareous nodules and have almost no internal drainage capacity (MDRE, 1999).

Around 700,000 ha of the cultivated land in the region is rain-fed, and is managed according to customary land tenure systems. About 100,000 ha of land is taken up by irrigation schemes administered by the State through agencies such as the Office du Niger (67,000 ha) and Opération de Segou (40,000 ha)[1]. These State agencies manage

[1] There are also 5,000 ha of sugarcane plantations that are managed by a Chinese company.

Figure 1. Mali and the location of the Office du Niger

the central irrigation infrastructure and allocate plots to farmers. According to official ON figures, nearly 300,000 tonnes of rice was produced in1998/1999, which amounts to about half of the entire country's rice production. The average rice yield in the Office du Niger is 5-6 tonnes/ha, while yields are much lower in the Opération de Segou scheme, where rice is cultivated with controlled submersion.

The ON has a multi-ethnic population of 250,000 people, 180,000 of whom are farmers. The 210 villages in the scheme house over 15,000 families. The natural population increase is about 2.6% per annum, but this is supplemented by a large number of people who have migrated to the scheme and to the nearby town of Niono (MDRE, 1999). There was a significant influx of people during and after the droughts in the 1970s and 1980s, and population density in the ON currently stands at over 51 people/km^2, which is double the density in the surrounding areas. Most people still live in extended families, although the number of nuclear families is rising.

As a result of the growing population, the influx of pastoralists after the droughts and the increasing number of livestock, there is tremendous pressure on natural resources in the irrigated area and the southern part of the surrounding region. The natural grazing and woodlands around the scheme are shrinking as more and more land is cleared and planted with rain-fed cereals (MDRE, 1999).

There is considerable variation in the size of farms in the scheme (see Table 1). Performance varies according to whether plots are located in run-down or rehabilitated areas, and one study has indicated that 43% of all farmers work in the rehabilitated area, where economic returns are highest (Baris et al., 1996).

Table 1. Characteristics of the farm types in the Office du Niger, their net costs and revenues (1995/96)

	Rehabilitated area			Non-rehabilitated area		
	Large	**Medium**	**Small**	**Large**	**Medium**	**Small**
% of farms	3	14	26	7	19	31
Total farm area	12.1	5.1	2.5	8.8	4.2	2.3
Area under rice	10.3	4.3	2.2	8.6	4.0	2.2
Yield (kg/ha)	7,700	7,300	6,500	3,400	3,600	3,400
Farm revenues/ ha Fcfa *	983,200	883,100	680,800	345,100	361,100	313,900
Cost rice/ha in Fcfa	188,300	201,500	220,700	143,600	159,600	165,200
Rice revenues/ha in Fcfa**	779,700	717,200	597,800	289,000	299,100	268,800

*Farm revenues: revenue from rice, vegetables and animals. **Rice revenues: revenue from rice in the main season. Price of paddy = 125 Fcfa/kg. As of January 2000, 1 $US = 600 Fcfa.
Source: Baris et al., 1996 and ON, 1997.

The development of the Office du Niger

The French colonial powers conquered Segou in 1890 and imposed taxes, forced labour, and military conscription on the local population. They turned cotton and groundnuts into cash crops, and after the discovery of the large inland delta they set up the Office du Niger irrigation scheme in the then sparsely populated area using forced labour, to produce cotton for France and rice for the colony's population.

When Mali gained independence in 1960 the new government was committed to heavy State involvement in promoting economic development, and it took control of the marketing and distribution of certain agricultural products. The body managing the Office du Niger remained under State control, and maintained its monopoly on the rice and cotton market. Cereal markets were not liberalised until 1988, when a structural adjustment programme shifted the emphasis to reforming and downsizing government-run rural development institutions such as the ON management structure.

The French initially planned to spend about fifty years developing an irrigated scheme that would eventually cover one million hectares[2]. In 1947 they completed a dam that diverted water from the river Niger, raising the water level by 5 metres and facilitating the potential irrigation by gravity of 1,000,000 ha of land (Aw et al., 1996). However, by 1982 the ON was still a long way from meeting its initial objectives. Fifty years after its creation, the scheme only irrigated 60,000 ha of land, and because the system was poorly maintained one third of the developed area was abandoned in the 1980s, as average paddy yields dropped to their lowest level of just 1.6 tonnes/ha. The settlers were also dissatisfied with their poor working and living conditions, as they had few rights, many obligations and could be summarily evicted by ON management (Aw et al., 1996).

The importance of the irrigation scheme has been highlighted by the major droughts that Mali has suffered over the last few decades, first in 1972-1973 and then in 1983-1984. In the 1970s a master plan was devised to renovate the scheme, and after an initial pilot phase remedial work began in 1982 (Aw et al., 1996). This was funded by various donors, on condition that the Malian government liberalised the production and marketing of rice, and gave farmers more influence in the scheme's management. By the end of the 1990s a total of 30,000 hectares had been overhauled, and work is set to continue over the coming years (Touré et al., 1997).

Donors have also funded initiatives to extend the scheme, and the Malian government aims to have added another 30,000 hectares to the ON by the year 2002. Also businesses will be able to apply for this new land. The farmers will be responsible for installing the tertiary infrastructure (a network of small feeder canals which serve one or more fields), and will therefore be expected to invest labour and money into the scheme. The main problem posed by this expansion is that some of the land earmarked for the scheme is currently used for grazing in the rainy season.

The body managing the ON was restructured in 1994, and has subsequently only been responsible for allocating land, maintaining the secondary infrastructure (main irrigation canals), and carrying out extension work. Since the restructuring, farmers have had some input into the way land is allocated and the secondary infrastructure maintained, as they now have a seat on the two committees that plan and monitor these activities. The State is financially responsible for maintaining the primary infrastructure (water intake and distribution), and the cost of maintaining the secondary infrastructure is covered by water fees levied from farmers, who also pay for the tertiary infrastructure. These responsibilities are outlined in the '1995-1998 contract-plan', which has been signed by the State, the ON and farmers' representatives.

Once the scheme was rehabilitated and its management system reorganised, productivity increased rapidly, and in ten years rice yields rose from 1.5 to 5.5 tonnes/ha.

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[2] See also Mendez del Villar et al., 1995; Schreyger, 1984; Jamin, 1995.

According to the ON, this was mostly due to better-regulated water levels on the irrigated plots and to farmers improving their crop production techniques: transplanting rice, using high-yielding varieties, and more mineral and organic fertilisers (Touré et al., 1997). General conditions also improved for the rice farmers as the paddy marketing and processing system was liberalised in 1985, and permanent roads were built in the region. Security of land tenure also improved, as farmers that paid their water fees and managed their land according to ON policy were able to obtain a heritable farm permit (see Box 1).

In January 1994 all the member states of the West African Monetary Union devalued the CFA franc by 50%. In addition to benefiting from the scheme's rehabilitation, farmers in the Office du Niger profited considerably from the liberal price climate in the first two years after devaluation, and were able to more or less dictate the price to buyers (Touré et al,. 1997).

Box 1. Land tenure in the Office du Niger

Land is administered by the Office du Niger through 5 different land tenure arrangements (decree No 96-188 P-RM of 1996):

1. Annual user's contract
2. Farm permit (PEA)
3. Lease for a house plot
4. Ordinary lease –30 years
5. Long lease –50 years

Provided that certain conditions have been fulfilled, the annual permit can be turned into a farm permit after the land has been cultivated for two years. Water fees must be paid, the 'tertiary' irrigation system maintained, and management oriented towards intensive rice production. In fact, few applications are turned down, and most farmers no longer apply for a farm permit as they feel that the annual user's contract provides sufficient security. Farmers that pay their water fees qualify for 'heritable' permits.

Some farmers sell their farm permit to other farmers or townspeople, although this is illegal. It is also common for farmers who are unable to cultivate all their land, or who need money, to rent land out for share cropping or for cash. The head of the family allocates some of the rice plots to dependents who use them to cultivate vegetables, and who may approach other families for more land.

The lease for a house plot is available to farmers and others who are more or less economically dependent on the ON. The 30 year ordinary lease is intended for people, projects and businesses that want to invest in the agro-sylvo-pastoral sector, and long leases for agro-processing activities.

The provision of credit and fertiliser

Farmers in the ON used to receive credit for purchasing equipment and inputs upon settlement. In the 1970s the ON had a monopoly on paddy marketing, and was also responsible for managing credit services until the 1980s, when donors created the Agricultural Input Fund (FIA). Credit was then supplied by Village Associations (VA), which were set up in 1984 so that rice production could be managed locally. The VAs were also responsible for recouping loans, but as many rice farmers saw it as 'money from the whites', they did not keep up with their repayments.

In 1990 the FIA was replaced by the Village Development Fund (FDV), which worked as a revolving fund. This meant that new credit could only be raised once outstanding loans had been paid off. In 1996 the FDV was replaced by the Fédération de Réseau des Caisses Mutualistes du Delta, a mutual savings and credit co-operative. There are now many different types of financial institution in the zone, and Niono has two banks and several savings and credit co-operatives. Farmers can also get access to credit by forming a producers' association, or 'Groupement d'Interêt Economique', but these are vulnerable to the same type of problems experienced by the VAs.

In addition to administering credit schemes the VAs buy and distribute fertilisers, and some also generate income through small-scale mechanised rice-threshing. Many of them have had problems with handling credit, through inexperience, dishonest board members, or because buyers of rice didn't pay for their purchases. Some of the VAs have run up serious debts, and have been unable to obtain credit for the next season because they could not meet their obligations to the bank. The situation seems to have worsened since 1994, and banks now apply strict regulations to recover their money. The VAs now also sanction bad debtors, and may appropriate part of their rice field and use the produce to pay off outstanding loans. When a whole village is compromised every farmer has to contribute 2 or 3 bags of rice per hectare until all the old debts are settled.

At present there are two ways of obtaining fertiliser. With the first method, the VA pools all the farmers' orders and then asks suppliers to quote for a bulk order. When they have made an agreement with a supplier they go to the bank, and the supplier is given credit for purchasing the fertiliser. The VA takes responsibility for repaying the bank, and collects funds from farmers, who either pay in kind or cash. If the VA has run up debts and cannot raise money from the bank, the farmers or village groups deal directly with the suppliers, either paying cash or arranging some kind of credit.

3 Farming in Tissana

The village of Tissana was officially established in 1955 and is located at a distance of 14 km from the town of Niono. The first twenty-six families in the village were given credit to buy agricultural equipment, and were allocated land on the basis of how many mouths they had to feed. Because of the drought, a large number of people moved into Tissana in the 1980s. The newcomers were not given leases for irrigated land nor loaned money to buy agricultural equipment, and those with no equipment either had to hire it or pay someone to plough for them. Many families could not survive by rice farming, and had to turn to other activities to make ends meet.

There are now more than 90 resident families in Tissana, and just under 20 non-resident farmers who work in the village fields. A village association was set up in 1985, but as a result of some unfortunate experiences and fraudulent rice buyers, it went into debt. The association is now recouping the money through compulsory contributions from every farmer in the village, and by only giving credit to farmers with no debts.

Remedial work on the rice fields in Tissana started in 1991. When it was finished, land was re-allocated to descendants of the initial settlers and to some of the newcomers. This time the allocations were based on the number of 15 to 55 year old males in each household, and several families were left with less land than before. The average holding has been shrinking since the 1970s, as land has become increasingly fragmented due to a growing population and by families breaking up into smaller units. Each household now cultivates an average of 4.8 ha of rice in the wet season and 1.1 ha of dry season rice, although the range within these figures is considerable. All households also cultivate some non-irrigated fields, which size has also decreased since the 1970s.

The cropping system

Until 1970 the main cash crop was cotton. Two-thirds of the area was under rice, which was grown as a subsistence and a cash crop, without the benefit of any fertiliser. People also cultivated millet, sorghum, cowpea and groundnuts in the rain-fed area, and grew vegetables on sites near the village. The Office du Niger supervised cotton cultivation,

and made the use of certain cropping techniques and mineral fertilisers more or less obligatory. An ON agent was stationed in the village, and told farmers how much fertiliser to use and when to apply it. The ON had a monopoly on buying and processing cotton and paddy.

Irrigated cotton production in the ON was wound up in 1970, as the rain-fed cotton production systems in southern Mali proved to be more cost effective. Rice took over as the main cash crop, and was initially directly sown on land ploughed by animal traction. Mineral fertilisers were applied to rice at the same rate as for cotton: 100 kg P/ha when it was sown, and 100 kg N/ha when the rice is 'heading'. Farmers grew photosensitive varieties of rice with long straw.

The programme of remedial work that started in 1991 involved levelling the fields, thoroughly cleaning the drains and constructing 1000 m^2 basins. As it became easier to regulate water levels in the fields, farmers started growing high-yield, non-photosensitive varieties of rice. These are now being replaced by varieties that are less sensitive to the yellow mottle virus, which caused considerable damage in 1993 and 1994. It quickly became standard practice to transplant rather than sow rice, and planting dates and densities also changed. The farmers use manure and mineral fertiliser on seed beds, and apply the recommended doses of 200-250 kg/ha urea and 100 kg/ha of DAP to the new varieties. A second rice crop is now grown in the dry season in a small, specially designated area. In 1996/1997 and 1997/1998 the average yield was 4.1 t/ha for rainy season rice and 3.0 t/ha for dry season rice.

The whole rice system has become more labour intensive, and there is now little out-migration from the ON. Labour shortages are increasingly common at peak periods when the rice is transplanted or harvested. Young people coming in from the Sahel are contracted to work for a task, a day, or a season (see also Brock and Coulibaly, 1999). Transplanting has become a specialised task that is mainly done by women from the villages, *Bella* people and certain day-labourers.

In the 1960s the farmers used to grow millet in non-irrigated land in the ON (known as the 'hors-casiers') but with successive droughts and declining rainfall the 'hors-casiers' became less productive over time. Before the irrigation system was overhauled, water from the drain used to leak into these plots, and farmers started using them for 'irrigated' cultivation, finding that they could significantly increase their income by using them to grow additional rice and vegetable crops. They could no longer do this after the drain was cleaned and repaired. Once it was overhauled this water supply more or less dried up, so they asked for help, and were granted permission to set up a pipeline (at their own cost) to tap water from an irrigation canal and feed it into the 'hors casiers'. The land is used to grow sweet potato, cowpea, maize, tomatoes, onions and some rice, but the irrigated area is much smaller than it was before the drain was repaired.

Tissana's 'hors casier' area has become officially destined for rice cultivation and is part of the planned extension of the ON. Tissana together with some 13 villages in the neighbourhood will benefit and some of the farmers involved have already negotiated a loan to pay for the investments.

Vegetable production

Farmers were previously not permitted to grow vegetables in the ON rice fields, as it was thought that this might have a negative effect on soil fertility and infect the rice crop with diseases. However, since research has indicated that this is unlikely, farmers are being encouraged to grow vegetables on the rice fields in order to diversify their production. Onions and tomatoes are the most important crops, and vegetable production is expanding fast. In 1995 vegetables covered 1,300 hectares of land, and by 1999 the figure had risen to 3,800 ha, 70% of which were used to grow onions (ON, 1997-1999).

Vegetables are mainly grown by young unmarried men and women, who are allowed to do so by the head of the family as a kind of pay-off for working in the rice fields during the rainy season. They do not usually get any advice on how to grow vegetables, and cropping techniques vary considerably. Between 1991 and 1997 the average yield for onions varied between 18 and 34 t/ha (URDOC, 1995-1998), but average tomato yields climbed from 19 t/ha in 1989 to 26 t/ha in 1992.

In 1994 a Malian tomato processing unit, SOMACO, started contract farming around Tissana as the area where they normally grew tomatoes was being rehabilitated. In 1996/1997 several farmers in Tissana grew tomatoes under contract to SOMACO, which provided seed, pesticides and instructions on how to cultivate them and treat the most common pests and diseases. The tomatoes were bought at a fixed price.

After the rehabilitation programme in Tissana was completed, a separate site was set aside for vegetables. This worked well initially, but for the last few years the site has been waterlogged in the dry season, and farmers have started growing rice on it. In the rainy season they use it to grow maize and okra. The ON wanted to concentrate vegetable production in a certain part of the rice basin in order to reduce water consumption in the dry season. The VA selected a site, and farmers with plots in the designated area hired out their land. These plots were well fertilised by the vegetable growers, who also paid the water fee. Although farmers said that keeping the vegetable plots together made it easier to protect them from straying animals, they only kept to the reserved site for a year because it was not large enough for their needs.

The livestock system

Rice farmers in the Office du Niger currently own an estimated 200,000 head of cattle, 36,000 of which are draught oxen that are used for ploughing. The farmers also invest some of their profits in livestock, which are tended by Fulani herdsmen who have a profit-sharing arrangement with the owners. In the dry season the cattle spend about six months feeding on stubble and re-growth in the rice fields. Some 27,000 hectares in the Niono area, for example, is grazed by about 81,000 head of cattle, 60 to 70% of which belong to rice farmers and people from Niono (URDOC, pers. comm.). In addition, many animals graze just outside the irrigated area, but drink from the irrigation canals.

The herds leave the Tissana fields in June/July, when rice cultivation starts and the first rains have started to fill the ponds in the surrounding areas. They are vaccinated and treated against parasites before leaving the irrigated area, and Fulani herdsmen take most of them to a zone about 30 km east of Tissana. They are not allowed to take them any further, as the owners like to be able to stay in touch. The oxen follow on in August after the ploughing has finished.

Herds usually return to the village when the natural water sources have dried up, although they sometimes go back earlier if the owners want to see their animals. They initially graze on fallow land in the 'hors-casier', and are let into the fields after the rice is harvested. Although the rice stubble is freely grazed, unofficial local conventions give first access to livestock from the farmer. The local radio generally announces when open access is to begin, and other herds from Tissana, neighbouring villages and elsewhere then go into the fields. The herds are watered in the canals and spend the rest of the dry season browsing rice straw. Most of the herd spends the night in Fulani cattle pens just outside the irrigated area, but sick or lactating animals and draught oxen are taken to communal or private pens near the village. Their feed is supplemented with salt, and they are sometimes given stored concentrated feed, rice bran and straw.

The natural grazing resources in the non-irrigated part of the Office du Niger and the adjacent area are intensively used. According to MDRE (1999), the sylvo-pastoral zones in the area south east of Niono are being used to capacity, and the declining ground cover, grasses, herbs, bushes and trees indicate that they are dangerously near over-use. The planned expansion of the irrigation scheme will further diminish the amount of land available for grazing, and reduce the herds' mobility (MDRE, 1999).

The farming economy

Rice

Between 1996 and 1998 the economics of rice production were monitored in 4 villages, one of which was Tissana (Table 3). Net revenues in Tissana were 130,000 CFA per hectare for 1996/1997, and 170,000 CFA per hectare for 1997/1998. The average household cultivates 4.4 ha of rice per season, and earned roughly 570,000 CFA per season in 1996/1997, and 750,000 CFA per season in 1997/1998. This amounts to a return of 2,200 CFA per working day for family labour[3]. These figures include rice grown for household consumption. The dry season rice is mostly used for home consumption and to repay loans raised to buy fertiliser.

The figures above may in fact be too low, as farmers from Tissana later admitted that the actual figures for yields were higher than they had reported. There had been problems with drainage in the rice fields in 1996, but they overstated the damage as they were worried that the Office du Niger might raise the water fees if their profits were too high. They had also been obliged to part with a lot of rice that year, as contributions to a health centre and to repay old debts.

The costs per hectare of rice are remarkably similar for different types of rice farmers. Studies have shown that this means that farmers in non-rehabilitated sites are at a disadvantage, because their costs are more or less the same as in the rehabilitated areas, but their yields are much lower (Baris et al., 1996). However, the figures indicate that it was still worthwhile investing in mineral fertiliser (see Table 2).

There is a need to develop more reliable methods for estimating the net revenue from rice, as it is used as the basis for determining water fees and other taxes. Several economic studies have come up with substantially different net revenues per hectare of rice, or for the entire farm. The figures for 1995/1996 varied from 175,000 CFA/ha for a small farm in a non-rehabilitated zone to almost 600,000 CFA/ha for the largest farms in rehabilitated areas (Baris et al., 1996). The reported revenues for 1997 and 1998 were lower (ESPGRN, 1997; 1998). Profit dropped in the 1998/99 season as costs increased and the price of rice fell (Kone, 1999).

Onions

It has been estimated that in 1995/1996 vegetables accounted for 20% of farm income, and that 95% of this came from onions (Touré et al., 1997). Most of the onions are sold at harvest time when prices are relatively low. Farmers have been trying to store more produce so that they can sell it later at a higher price, but they lose a significant amount to rot and weight loss, and can expect to lose about 50% of their stock over 3-6 months of storage. They are trying to improve their storage methods, which can be seen from the levelling out of price fluctuations.

[3] The daily rate for a labourer is normally 1,000 CFA.

Table 2. Costs and net revenue per hectare of rice for various types of farms and villages in 1996/97 and 1997/98

Zone and type of farm	1996/97 season			1997/98 season		
	Costs CFA/ha	Yield kg/ha	Net revenue CFA/ha	Costs CFA/ha	Yield kg/ha	Net revenue CFA/ha
Large farm (8)	230,800	4,490	218,200	224,800	4,000	205,000
Medium farm (12)	229,700	4,070	177,300	240,600	4,350	194,400
Small farm (15)	231,100	4,000	168,900	227,000	3,750	148,000
Tissana (10)	228,200	3,610	132,700	248,800	4,200	170,700
Gnoumanke (8)	228,500	4,700	242,000	235,400	4,380	203,000
Ringande (9)	252,600	4,780	225,000	241,000	4,760	235,000
Hamdallaye* (8)	207,400	3,510	143,500	188,000	3,140	125,700

* not rehabilitated.
Source: ESPGRN, 1997 and 1998.

Table 3. Revenue from vegetables grown on plots managed by households and individuals

Category of household	Revenue (in CFA)		
	Household	Men	Women
1 (better-off)	978,000 (1)	98,400 (18)	85,300 (22)
2 (average)	123,000 (2)	36,300 (13)	43,300 (18)
3 (least well-off)	45,800 (5)	55,500 (16)	35,300 (20)

Figures in parentheses represent the number of cases of vegetables. Data for 1998.
Source: ESPGRN, 1999.

Table 3 shows that onions provide a source of income for both households and individuals, and that people from Category 1 (see next chapter) farms earn the most from growing onions. More vegetables are grown by individuals than as a collective venture. The income earned from growing vegetables may be used to contribute to social events, to pay for labour and inputs, and to buy consumption goods. Men also use some of it to satisfy personal needs, and young men use it to pay engagement expenses. Young women put some of the money aside for their own dowry, while older women contribute to their daughters' dowry. Money earned by the household is usually used to cover general farm expenses.

4 Soil fertility management

Categories of farmers

Farmers in Tissana stated that soil fertility levels can be maintained by applying the recommended doses of mineral fertiliser, and by using organic fertilisers such as rice straw, which they particularly recommend for alkaline soils. Rice crops also require well-ploughed fields and good dykes to maintain and control water levels in the field. Other important factors affecting soil fertility management are access to a means of transport, and a certain amount of 'courage' from the workers and head of the farm, although the latter is obviously very hard to quantify.

The farmers were asked to classify all the farms in their village according to how they manage soil fertility. The criteria they selected were: the amount of irrigated land under cultivation; the number of family workers in the household; the availability of agricultural equipment such as draught oxen, ploughs and donkey carts; the correct use of mineral and organic fertiliser; and courage. They then categorised the households into the following three groups:

Group 1	Farms in this group own cattle and at least one complete set of agricultural equipment. They have plenty of available labour, use organic fertiliser and apply the correct amount of mineral fertiliser.
Group 2	Farms in this group do not have a complete set of agricultural equipment, although they do own some implements. They possess some animals and have an average number of workers in the household.
Group 3	These farms do not own animals, have little equipment, and only a few workers. They have to borrow equipment to work the fields.

Table 4 presents some data for these three categories.

Table 4. Average resources available to each category of farm in Tissana

Category	Sample size	Area under rice (ha)	Double cropped rice	Vege tables	No. of adults	No. of Draught oxen	Donkey Carts/ Farm	Ha/ adult	Ha/ pair of oxen
1	8	6.6	1.7	1.0	11.0	4.1	1.4	0.8	3.6
2	8	3.8	1.0	0.7	9.7	3.4	1.7	0.4	2.4
3	5	1.5	0.5	0.3	3.6	1.6	0.8	0.5	1.6

Average data for 1995-1997.
Source: own survey.

Table 4 shows that the categories of farm developed during the participatory research are partly based on production capacity, and can therefore be seen as a function of available resources. The category of "most capable soil fertility managers" generally cultivates more land, and has more family labour and other resources. The average figures for rice yields and fertilisers used in 1995-1997 are given in Table 5 below. On average, Category 1 farmers produce rice more efficiently than their counterparts in terms of kg per worker.

Table 5. Use of inputs and rice yields for each category of farm in Tissana

Farm category	Main season				Dry season				Rice
	Urea (kg)	DAP (kg)	Cartloads of manure (No.)	Yield (kg/ha)	Urea (kg)	DAP (kg)	Cartloads of manure (No.)	Yield (kg/ha)	Yield/ worker (kg)
1	208	105	3.1	4,300	183	32	1.6	3,000	3,500
2	209	96	5.3	4,200	169	53	0	2,800	1,900
3	225	103	4.5	4,300	126	65	0	3,300	2,900

Average data for the main season (1995-1997) and the dry season (1996-1997).
Source: own survey.

The three categories produced fairly similar amounts of rice per hectare, and in the main season they used more or less the recommended doses of mineral fertiliser. There were greater variations in the amount of manure applied, and about half of the farmers only used it in small quantities.

Within a season, the yield per hectare did not differ very much across the three categories, which seems to suggest that cropping conditions and the use of inputs are comparable for all farmers. There were greater differences in yield between the three seasons studied.

Organic fertilisers

During the diagnostic study it became clear that farmers are well aware of the benefits of using organic fertiliser. They said that it improves the soil in the rice fields, making it softer and easier to work. They reported some nutrient depletion in the fields that have been cultivated since the 1950s, and that they now need to use three bags of DAP to maintain productivity in these fields, while they had previously managed with two. Some farmers said that they thought that over-reliance on urea and DAP may eventually impoverish the soil and adversely affect productivity.

Farmers are also concerned that mineral fertilisers have become more expensive since the devaluation of the CFA franc in 1994. As the price of rice has also increased, most of them think that profits have gone up too, but they are still worried about the cost of using large quantities of mineral fertiliser, and are interested in finding alternative sources of nutrients. They would like to produce and use more organic fertilisers, and although they did not seem interested in applying manure directly onto rice, its use on vegetables does indirectly benefit subsequent crops. Not surprisingly, farmers who have run up debts are particularly interested in finding ways of reducing the cost of inputs.

After the CFA was devalued, the ON and the research and extension service URDOC started to promote composting. They organised a series of radio programmes and village-level demonstrations, whose main focus was on helping farmers to save money by finding alternatives for various mineral fertilisers. Some of the ON staff feel that organic inputs are no substitute for mineral fertilisers, although they concede that they do improve soil structure and can help to maintain and improve soil productivity by raising the cation exchange capacity (see Box 2).

The amount of manure farmers can produce largely depends on how they manage their livestock. They usually collect some rice straw for resident oxen, lactating cows and donkeys, but only store a limited amount because there is not enough space in the compound, and the straw is also liable to be eaten by termites. Farmers estimate that grazing animals consume 40% to 80% of all crop residues during the dry season, and as many of the livestock do not belong to the farm where they are grazing, most of the

Box 2. Introducing Composting

The idea of composting rice residues in the field developed during the action-research in Tissana. No transport was needed, the canals provided an easily accessible source of water, and farmers could speed up the process and improve the quality of the compost by adding cattle dung and urea. Four farmers tried the technique in 1995/1996, eight picked up on it the following year, and two Category 2 farmers were still composting rice straw in their field after the research finished. As Category 3 farmers are particularly short of transport it was thought that they would benefit most from this exercise, but as they also lacked the necessary labour they remained largely uninvolved.

nutrients in these residues are lost from the cropping system. The greatest losses are sustained by Category 3 farmers, who own the fewest cattle. Some dung is left on the fields by grazing animals, but most ends up in the Fulani cattle pens at the edge of the irrigated land. The dung left in the field will not have much impact on soil fertility, as most of the nitrogen will be lost, and the rest is turned into dust and blown away by the wind during the dry season.

There is a certain amount of competition between rice cultivation and livestock production systems within the ON. The management has always focused on intensifying rice production and has never really paid much attention to livestock management, but has frequently complained that cattle damage the irrigation system and dry season crops. The competition is unlikely to improve, given the growing interest in vegetable production during the dry season. The solution may lie in intensifying livestock production, particularly if this also reduces the number of cattle held by farmers. The farmers would need to grow fodder crops in the dry season, which would not constitute an entirely new development, as they are increasingly using cowpea, groundnut, sweet potato and maize residues as fodder.

Tests conducted with farmers on the production of fodder crops such as *Dolichos lablab* and Phasey bean (*Macroptilium lathyroìdes*) indicated that they are willing to produce them, but not if it means sacrificing land that they would otherwise have used to grow vegetables. They want to enlarge the dry season cropping area and grow additional fodder crops, but at the moment they prefer fodder crops such as cowpea, which can also be used for human consumption. Another advantage of producing fodder in the dry season is that it does not have to be stored for long (ESPGRN, 1997 and 1998b). Storage is a real problem that needs to be addressed before farmers can consider growing fodder crops on a large scale. There are techniques for compressing fodder and preventing termite attacks, but at the moment they are seen as too expensive.

As onions generate more income than any other vegetable, farmers are prepared to invest in fertilising them. Most of the onion fields are fertilised with organic inputs, although farmers will use mineral fertilisers if they cannot get hold of enough manure or other organic matter. In a sample of 21 producers, just 3 used only mineral fertiliser and no manure. The amount applied per hectare diminishes as the cultivated area increases, which means that Category 3 farmers use the highest concentration of manure, as they have the smallest vegetable plots.

Manure is available from several sources. Some is produced in pens near the homestead where farmers keep some cattle and small ruminants in the dry season. These pens account for about two-thirds of all the manure used in the rainy season, and approximately half of what is used in the dry season. The rest is obtained from Fulani cattle pens just outside the irrigation scheme. This is supplied free of charge to livestock owners, while other farmers have to pay cash or in kind.

Partial nutrient balances for rice

As part of an exercise to monitor rice production and the use of fertilisers and crop residues, farmers drew up resource flow maps that were used to calculate partial nutrient balances for rice production. The straw content and nutrient composition of various rice products were largely estimated on the basis of published data (see Appendix). Residues incorporated into the soil during ploughing were not considered as an output.

Table 6 presents the nutrient balances for the main rice season and the dry season of 1997. The partial nitrogen and phosphorus balances are positive, because farmers generally use the recommended doses of urea and DAP on the main season crop. However, the balances for dry season rice are less positive and even negative for Category 3 farms. Farmers use fewer inputs in the dry season, when there is greater risk of crop failure. One reason is that the rice varieties used are not entirely adapted to the weather, which goes from being relatively cold to very hot in only a few weeks. The grain outputs are also lower, which more or less balances the nutrient budget.

Table 6. Nutrient balances per farm category (in kg/ha/yr)

Farm category	**Category 1**			**Category 2**			**Category 3**		
Nutrients	**N**	**P**	**K**	**N**	**P**	**K**	**N**	**P**	**K**
Main season									
IN	116	21	3	135	21	6	137	24	4
OUT 1 grain	-54	-9	-17	-54	-9	-17	-60	-10	-19
OUT 2 residues	-30	-4	-51	-31	-4	-60	-32	-3	-45
Total OUT	-84	-13	-68	-85	-13	-77	-92	-13	-64
Balance per hectare	32	8	-65	50	8	-71	45	11	-60
Dry season									
IN	95	7	3	107	9	0	52	4	0
OUT 1grain	-29	-5	-9	-39	-6	-12	-32	-5	-10
OUT 2 residues	-22	-3	-43	-30	-5	-68	-21	-3	-46
Total OUT	-51	-8	-52	-69	-11	-80	-53	-8	-56
Balance per hectare	44	-1	-49	38	-2	-80	-1	-4	-56

Data from 1997/98 main season and dry season rice.
Source: Own survey.

The negative partial balance for potassium confirms that insufficient inputs are applied to compensate for losses sustained through free grazing. At the moment the potassium reserves seem to be healthy, as the first 40 cm of soil contains about 600 kg of potassium that is immediately available for uptake by plants. However, there is a longer-term risk that essential nutrients may be seriously depleted if farmers do not start balancing the supply of inputs. Such depletion may have already occurred in the Macina

area, where irrigated cultivation first started, and where soils are generally sandier and inherently less fertile than the soils of Tissana.

The ON and a private fertiliser company from the Ivory Coast are currently testing new types of compound mineral fertiliser in the Macina area. In 1999 a new mineral fertiliser containing K, S and some minor nutrient elements such as Zinc, came on the market. It is commonly known as *sugube sugube*, and is in great demand, particularly in the Macina area. This suggests that farmers are becoming aware of the risks of nutrient depletion and are starting to take preventive measures.

It is possible that the positive balance for nitrogen may not actually exist, as nitrogen is quite volatile, particularly when it is in the form of urea. Field research in Sahelian rice-based irrigation systems has shown nitrogen recovery rates of as little as 5%, and an average recovery rate of 30% to 40% (Wopereis et al., 1998; Wopereis et al., 1999). We have not included a correction factor in this balance, for several reasons. Firstly, if we include losses through volatilisation, we should also include gains from the nitrogen fixing processes that occur naturally in a watery environment, and through the water-borne fern Azolla. Secondly, recovery rates were found to be highly variable, which made it difficult to apply one correction factor across a variety of situations. And thirdly, the nitrogen recovery rate must be adequate given that high rice yields cannot be achieved when there are serious shortages of nitrogen, on soils having a low inherent availability.

Taken as a whole, this is a remarkably stable system in terms of nutrient inputs and outputs. The single most important factor affecting crop performance seems to be the fact that the water supply is assured. As farmers can rely on stable growing conditions their risks are minimized, and they have the opportunity to invest in intensifying rice production. As the soils have very low levels of available nitrogen, and low to average levels of phosphorus, farmers get good results from applying nutrients in the form of urea and DAP. Specialists say that yields will increase even more if extra nitrogen is used (Wopereis et al., 1998), and some farmers are already using very large doses of urea on their rice crop.

As noted earlier, the nutrient balance for the dry season rice cropping system is less positive, which results in lower yields. The site selected for double cropping, has also been cultivated since the 1950s. These data confirm farmers' doubts about double cropping and their fear that it may reduce soil fertility, although this has a limited impact on the system as it only involves a small area.

Soil fertility problems in the Office du Niger

Soil studies have shown that levels of indicators such as C, total N, C/N ratio, P and K declined between 1951 and 1980. Some soils are becoming degraded and more sodic

and alkaline, and have reached critical levels in certain sectors of the irrigated scheme. The most problematic areas are double rice cropping sites (N'Diaye, 1998).

As soils become more degraded they become compacted, less permeable and porous. This has happened in small parts in one sector of the scheme, Kala Inférieur, where crops develop poorly in the hard soil, and fertiliser seems to have no effect. However, the impact of soil degradation seems fairly marginal at the moment, as the rehabilitation work and restructured management has improved overall crop performance. Improvements in the regulation of water levels in the rice fields have also helped to stabilise pH levels, and to minimise the impact of soil degradation on crops (N'Diaye, 1998).

The first results of a test conducted on degraded sandy soil indicate that the organic fertilisers used on the vegetables help arrest the effects of alkalinity (Dicko, 1999). Residual alkalinity has become widespread in the Niono area. Alkaline levels rise during the dry season, but drop again when the land is properly irrigated and drained. It seems that the common practice of watering vegetables with a bucket causes alkaline levels to rise. Vegetable production is therefore something of a mixed blessing despite the fact that the organic fertiliser is good for the soil. Farmers could change the way they water their vegetables, but it seems that they are either unaware of different methods, or unwilling to try them.

5 Discussion and conclusions

The Office du Niger is a very dynamic area, where the economic developments of the last decade have encouraged farmers to invest in their crops and fields. Since the scheme's management was restructured, farmers have been able to count on a reliable water supply and improved security of tenure, and have increased their income by diversifying into vegetable production.

However, if the net income from rice farming falls short of household needs and expectations, there is a danger that farmers will invest less in soil fertility management, and will not be able to sustain long-term productivity. It is therefore important that the tax burden does not become too great, and that reliable methods are developed for calculating the economics of rice farming.

Farmers need to use more organic supplements to keep their soils productive, and they therefore have to find sources of organic fertiliser. Cattle manure would be a logical choice, which makes the present lack of integration (and even incompatibility) between intensive rice production and extensive livestock rearing particularly unfortunate.

There are two recent developments in the ON that have positive implications for soil fertility. The first relates to the crop production system. A growing number of farmers are using organic fertilisers on the vegetables they grow in rice fields, which indirectly benefits the subsequent rice crop. They cultivate vegetables on relatively infertile sites, and rotate the vegetable plots in order to make the next rice crop more productive. Tests carried out in 1996/1997 and 1997/1998 clearly showed the benefits of these cropping methods for rice yields (Doumbia and Koné, 1998).

The second development relates to the animal production system. Several farmers have started stall-feeding resident animals, which should reduce the damage to the irrigation infrastructure and also provide a source of manure closer to the fields. These farmers may find it profitable to produce fodder crops, which would further stimulate supplementary feeding and also keep the oxen in good condition. The fodder could also be used for fattening oxen and sheep, and to increase milk production. There is the need

and the potential for more specialised animal production within the Office du Niger, and it may be that this is the start of such a development. This would entail using part of the irrigation scheme for livestock production, and there is a proposal in hand to designate 5,000 ha for fodder crops, and eventually set aside space for grazing (MDRE, 1999).

The big issue is the current expansion of the irrigation scheme. The expansion has gained a lot of support because it will secure many people's livelihoods, but it will also eat into neighbouring grazing lands and affect natural resource management in the Office du Niger. If the number of livestock continues to mount, pressure on the remaining grazing lands will increase accordingly. An environmental study carried out in 1997-1998 (MDRE, 1999) developed various scenarios to assess what impact different development schemes would make by the year 2010. It concluded that expansion must include measures that will reduce environmental impacts within and outside the irrigated area. This would involve improving water management, introducing wood and fodder production in the irrigated area, and consolidating services such as education, healthcare and credit programmes. Some provision has then been made for a growing human population, but for cattle the situation remains more difficult. If major problems are to be averted, livestock production will have to intensify and animal movements within the irrigated area controlled. One option is to deepen certain ponds and install wells to attract livestock to areas outside the irrigated area.

The ON needs to diversify the range of activities within the scheme in order to provide more security for the farming families living there. Vegetable production is already under way, and other possibilities include enlarging rice farms or involving agri-business in crop production and rearing livestock. Diversification should also focus on tree planting and wood production. These new types of activities and enterprises are included in the latest master plan for the Office du Niger, which is gradually being implemented. The Office du Niger is an area with tremendous potential, but as the environmental study indicated, sustainable development will only be possible if the expansion of the irrigation scheme includes measures that protect the environment.

Appendix

Partial nutrient model

The partial nutrient model used for calculating nutrient balances is based on four input/output functions:

IN 1 = application of inorganic fertilisers,
IN 2 = application of organic fertilisers,
OUT 1 = grain produced,
OUT 2 = crop residues that leave the field, including those burned (loss of N) or grazed.

Conversion factors and content data used for calculating nutrient balances

Product	% nitrogen	% phosphorus	% potassium
Rice grain	1.22	0.20	0.39
Rice straw	0.72	0.11	1.60
Animal manure	1.2	0.2	1.54
Urea	46	–	–
DAP	18	21	–

Source: Duivenbooden, 1992; ADRAO,1995; 1996; Anonymous, 1987.

Fertility status of the rice soils in Tissana

Parameter	Depth (5 samples)	Depth (6 samples)
Depth in cm	0 –20	20-40
Sand	49	37
Clay	20	33
pH-water	6.4	6.9
Nitrogen	0.016	0.007
P Bray	6	4
K available	0.23	0.28
CEC 49	11.7	16.3

K and CEC in meq per 100 g soil.
Source: Labosep, IER, Mali

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This discussion paper series has been launched as part of the NUTNET project. NUTNET stands for Networking on soil fertility management: improving soil fertility in Africa-Nutrient networks & stakeholder perceptions. NUTNET is co-ordinated by AB-DLO, The Netherlands. It brings together several research programmes working on soil fertility management in sub-Saharan Africa. Activities include research on farmer management of soil fertility and understanding of the perceptions of different stakeholders towards how best to improve soils management.

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