A Holistic Approach to Irrigated Rice Farming Problems Uncovers More Than Just Soil Degradation

AT FIRST sight, Foum Gleita in southern Mauritania is an ideal place for irrigated rice farming. But less than ten years after the construction of a dam to provide the necessary quantity of water, farmers were complaining of salinity problems and abandoning fields. A WARDA scientist came across the site in 1996, and decided it would make an ideal field-laboratory for soil-degradation studies, but first they had to gain the farmers' confidence by looking at the problem as they perceived it.

Background

The dam across the Gorgol River, constructed with funding from a variety of donors (including the World Bank) in 1984, created a large artificial lake with a normal retention capacity of about 500 million cubic-meters of water. This enables gravity irrigation of the land downstream, and the gentle land slope (1–2%) equally allows for gravity drainage back into the river. By 1989, the infrastructure was in place to irrigate some 1950 hectares of land for rice cropping. Initially, yields were reasonable (4.6–5.2 tonnes per hectare), but declined rapidly to 2.7–4.6 t/ha in 1992–1996. By 1993, some 237 ha had already been abandoned by farmers.

In 1996, a joint WARDA/ORSTOM (*Institut français de recherche scientifique pour le développement en coopération*, now *Institut de recherche pour le développement*, IRD) mission looking at salinity and alkalinity problems in the Senegal River valley arrived at the site to find the local extension service (*Societé nationale pour le développement rural*, SONADER) eager for partners to help them resolve the problems that the local farmers were facing. "Foum Gleita irrigation water contained positive calcite residual alkalinity—a sign that soil degradation may occur upon concentration in the root zone," explains Marco Wopereis, WARDA agronomist and member of the 1996 mission. "We decided that the site may be a useful field-laboratory for studying the processes of soil degradation in general, and alkalinization in particular." The hypothesis was that the concentration of alkaline water may lead to faster degradation of the soils of Foum Gleita than at other sites along the Senegal River valley, and that the site may act as an early-warning system of what might occur elsewhere in the longer term.

With this in mind, the UK Department for International Development (DFID) is funding a three-year project to determine the extent of the degradation problem, and the principal degradation processes, to establish and provide training to the extension service on a system for monitoring soil and water quality, and to develop low-cost alternative land and water management options tailored to the farming context (*see* Box).

The DFID Soil Degradation Project

International organizations
- West Africa Rice Development Association (WARDA/ ADRAO)
- International Water Management Institute (IWMI)

National research institutes
- *Centre national de recherche agronomique et de développement agricole* (CNRADA, Mauritania)
- *Institut de l'environnement et des recherches agricoles* (INERA, Burkina Faso)

Extension services
- *Societé nationale pour le développement rural* (SONADER, Mauritania)
- *Authorité de Mise en Valeur de Vallée de Sourou* (AMVS, Burkina Faso)

What the farmers said and what the researchers thought

At a workshop in June 1998, farmers complained that the areas north of the Gorgol River were degraded (most of the abandoned fields were north of the river), and that soil salinity was a major constraint to rice production. They felt a strong need for immediate solutions to this problem from the researchers. However, at the same time, they were highly skeptical of researchers in general—previous research into the soil degradation problem at the site had neither involved them personally nor yielded any concrete results that either extension or farmers could understand.

Researchers and extension workers from WARDA and Mauritania took a more holistic view, however. Although salt patches were observed on the soil surface, it was not at all clear that salinity was actually the principal constraint facing rice production, but it could easily become so in the future. In either case, soil degradation by alkalinization is a long-term process, and researchers would need more time to achieve practical results than it appeared the farmers were prepared to give them. Thus, WARDA decided to look at the farming practices at the same time, with a view to making recommendations for improving production in the short term.

Work elsewhere showed that the alkalinization process is practically irreversible, and can severely affect yields. Alkalinity occurs as a result of the build-up of carbonate salts in solution, especially in relation to relatively low concentrations of calcium and magnesium (*see* Box).

Researchers follow clues along the way

Thus, the research became broad based, looking at two themes at the same time: soil degradation and farming practices.

A first step was to map salinity throughout the scheme by means of a tool (known as EM38) that does not require soil sampling and extensive laboratory studies—this mapping was conducted in collaboration with the *Centre national de recherche agronomique et de développement agricole* (CNRADA) and SONADER. The study revealed that soil salinity was in fact very low at Foum Gleita, and that abandoned soils were not necessarily those with the highest salinity. A surprisingly poor relationship was found between EM38 and laboratory salinity tests of the same soils. The reason for this was discovered by our partners at IRD: precipitated minerals, such as calcite, did not affect the EM38 readings since they were not in solution in the soil, but the laboratory process redissolved much of these minerals, giving higher salinity readings. The lab tests revealed alkalinity in the Foum Gleita soil, but not to the same extent as that found in the Office du Niger scheme in Mali, where good rice production is still achieved. Thus, we were a little skeptical of the farmers' assertion that salinity was their major production problem.

Next, WARDA Sahel staff applied their standard suite of farming-practice tools to the situation in Foum Gleita. They monitored farming practices 'on the ground'; conducted nutrient-omission trials on both 'good' and 'problem' soils, in which nitrogen, phosphate or potassium are deliberately not applied to individual experimental plots to

What is alkalinization?

Although both are associated with what we term salts, the processes of 'salinization' and 'alkalinization' are qualitatively different: salinization occurs in the presence of sodium chloride and calcium sulfate with minimal carbonate ions, while alkalinization is a result of high concentration of carbonate ions in relation to calcium and magnesium.

All the main Sahelian rivers have a positive calcite residual alkalinity. Soils that are relatively rich in calcium can buffer irrigation-water alkalinity. However, if soil leaching (that is, flushing out of salts by the irrigation water) is insufficient, and no preventive measures are taken, this buffering capacity will eventually run out. Eventually, the soil solution will consist mainly of carbonate and sodium ions, leading to an increase in 'exchangeable sodium percentage' (sodication), and a rise in pH (alkalinization). Sodication eventually destroys the soil's structure, resulting in an impermeable mass, like concrete. Although rice can still cope to some extent with such unfavorable soil properties, other non-flooded crops cannot. The complexity of alkalinization and sodication makes them difficult to recognize. In addition, the processes are rather irreversible in practical terms, because of the costs involved in adding acid and gypsum in combination with heavy machinery needed to plow these products into the soil. For this reason it is essential to monitor alkalinization (and sodication), so that we can intervene before sodication destroys the soil structure. The advantage of the Foum Gleita site is that the initial alkalinity readings were three times the average of the Senegal River valley, so alkalinization will occur here much earlier than it will in the larger valley. Thus, we can use Foum Gleita as a field-laboratory for what might happen on a wider scale in the future.

To make matters worse, increasing alkalinity reduces the solubility of phosphate, and this too is lost from soil solution. This is the major cause of poor rice performance in Foum Gleita, where no phosphate fertilizer is normally added to the crop.

In the nutrient-omission trials, a no-phosphate treatment (center) stands out clearly among the others

determine their relative importance; and conducted trials to determine the efficiency of farmers' fertilizer regimes, by leaving small plots within farmers' fields unfertilized (known as T0 plots—see *WARDA Annual Report 1998*, pages 18–19). In addition, variety trials were conducted to see if there were varieties available that would perform better under farmers' management than their existing varieties. At various times during the season, the SONADER extension agents gathered groups of farmers to assess the trials.

As expected from our initial skepticism, the potential for rice production in Foum Gleita is a lot higher than one would assume from the farmers' performance, and a whole series of management practices contributed to the low yields achieved there. Farmers used poor-quality seed, and took little care of the seedbed. Land preparation (or soil tillage) prior to transplanting was either minimal or completely absent. Phosphate fertilizer was never applied, and nitrogen fertilizer poorly managed. Both sowing and transplanting were carried out rather later than at the optimal time. Transplanting itself was poor, both in terms of depth and spacing between plants. The rice fields were not drained when the grains matured, and harvesting was delayed and took a long time (up to one month)—resulting in loss of grain and quality. However, when comparing soil

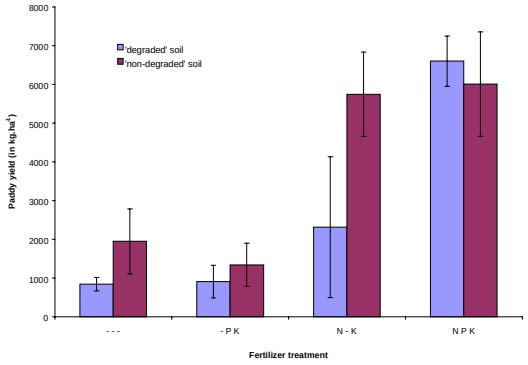

Figure 7. Nutrient-omission trials, dry season 1999: Not applying phosphate to 'problem' soils renders other management practices effectively useless—farmers normally achieve in excess of 2 t/ha with their current practices

Rice seedlings are often transplanted by young children, who are paid on an area basis (about US$ 15 per hectare)—this leads to sloppy work, with plants being placed too far apart and not properly imbedded in the soil. Note also that there was no prior land preparation

and lab tests with rice performance in the fields, there was a clear relationship between the level of soil alkalinity and rice grain yield: the higher the alkalinity, the lower the yield. But the experience in the Office du Niger scheme suggested that the levels of alkalinity in Foum Gleita could not account directly for this yield loss, so what is going on?

The answer lay in the results from the nutrient-omission trials, where even with optimal management of other fertilizers, experimental plots on 'problem' soils without phosphate fertilizer gave yields close to what the farmers achieved (Figure 7). It was already known from elsewhere that phosphate and zinc can become deficient—that is, inadequate to support plant growth—in alkaline soils. Moreover, during one field-visit meeting of researchers, extension agents and farmers' cooperative leaders, the farmers were asked to indicate the location of the 'problem' soils on a map. When this was compared with an earlier soil map prepared for SONADER, there was a clear link between farmer-perceived 'problem' soils and research-determined shallow (less than about 80 cm deep) soils. Graphical representation of these fields in terms of topography (that is, position on the valley slope and depth of soil) showed a clear relationship with yield in unfertilized (T0) plots and that in farmers' fields (Figure 8).

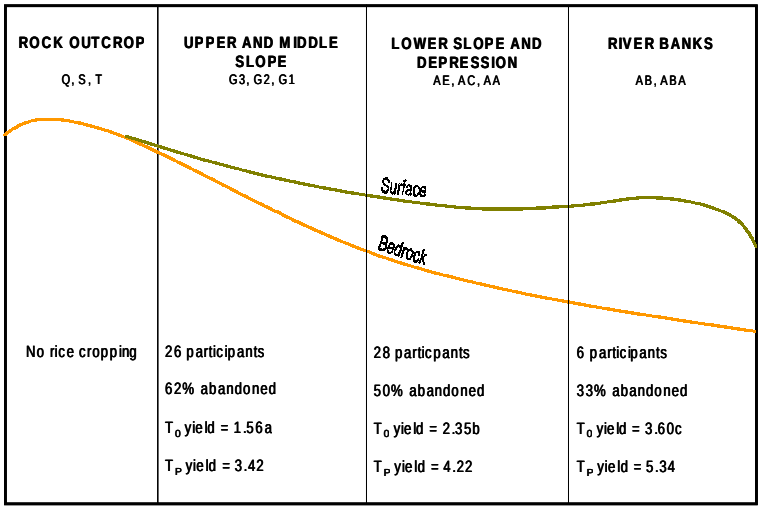

Figure 8. Toposequence diagram showing farmers' performance (% farmers abandoned, Tp and T0 yields) as a function of topographic position and soil depth.

Subsequent detailed soil analysis revealed that alkalinity increases within the soil as one approaches the bedrock. It is this schist bedrock (or parent rock) that is the source of the carbonate, which is released by water action into the adjacent soil. In the shallower soils, the alkalinity is clearly much closer to the plant roots, and results in the phosphate-deficiency problems that depress rice yields.

Despite all this, however, very few of the soils at Foum Gleita would warrant classification as 'degraded' according to internationally recognized scales. At an end-of-season workshop for sharing the research results with farmers, WARDA researchers emphasized the importance of improving farming practices as the route to improved rice production (*see* Box).

Changing perceptions and their scientific and socio-economic bases

In the dry season of 1999, SONADER agents again monitored farmers' practices and additionally asked them to rank constraints to production in order of importance. Overall, farmers no longer consider salinity as a very important problem, although the average across the various soil-types masks the views of those farming on 'problem' soils, who continue to see salinity as a problem. After bird damage, the availability of fertilizers is the major production constraint. This is well known to WARDA, as phosphate fertilizer is rarely available to farmers in Mauritania—perhaps because it was never part of the old 'blanket' fertilizer recommendations, and therefore farmers could never obtain credit from the bank to buy it.

Farmers claim to be sufficiently aware that their farming practices are not optimal, but blame external forces such as the availability of credit (to buy inputs—seed, fertilizer), phosphate fertilizer, and labor for their inability to improve the timing of various activities (sowing, transplanting, fertilizing).

Researchers also blame the majority of the problem on suboptimal management practices and acknowledge the importance of external factors, such as the availability and

Recommendations for improving rice production at Foum Gleita

In a way, WARDA has now 'done its job' for the extension services and farmers at Foum Gleita. All they now have to do to improve their farming system is to implement the following practical recommendations—but they still face numerous constraints, some of which are not under their control.

- Seedlings should not be left in the nursery too long, but rather transplanted while young and vigorous.
- Fields should be tilled in advance of transplanting.
- Transplanting requires better management, particularly in terms of plant spacing and secureness within the soil.
- Fertilizers need careful management, in particular phosphate needs to be applied and the timing and dosage of nitrogen needs better control—minimal improvement in production is possible on the 'problem' soils without the addition of phosphate (see text for problems with phosphate availability); once that is resolved, proper management of nitrogen can increase yields still further, as it already will on the 'good' soils.
- Fields should be drained before harvest, and then should be harvested soon after maturity and quickly.
- The adoption of new varieties could increase yields by a further 10–25%.

Comparison of farmer's practice (foreground) with trials demonstrating improved management—farmers were clearly falling far short of potential

price of inputs. However, they also attribute low yields to lack of knowledge on the part of the farmers themselves, in addition to poorly organized farmers' cooperatives. Researchers do, however, recognize the potential of the alkalinization problem getting worse—therefore, strategic research is needed to monitor soil degradation. Equipment has been placed in various fields to monitor water movement and properties as part of the long-term research.

Moctar Ould Isselmou, formerly *Chef Service de Vulgarisation* (that is, in-charge of the extension activities) at Foum Gleita, and now *Chef Service Vulgarisation et Recherche en Milieu Paysan* (Head of Extension Services) for SONADER as a whole, sees the current problem mainly as one of finances. "Initially, we had a World Food Programme 'Food for Work' program in place, whereby farmers of the various cooperatives maintained the irrigation canals, for which they were given food and also earned a reduction in their contribution to SONADER for scheme upkeep." Primary and secondary canals are shared among cooperatives, but are managed by SONADER—a service for which the cooperatives have to pay, if they want SONADER to release water from the secondary canals into their fields. With the abrupt removal of the 'Food for Work' program (in 1992), farmers are no longer motivated to do their bit in canal maintenance.

Moctar again: "When we had external funds, SONADER bought the seed and fertilizer for the whole scheme, and farmers paid us back out of their profits. Now they have to buy these inputs commercially and pay for them at the time of receipt, as well as paying their contribution to SONADER for scheme upkeep." The cooperatives have major problems coordinating the payments: many farmers pay their contributions late, so the season starts late, with subsequent loss of yield. Some farmers also delay paying back their bank credit, so cannot draw further credit for buying inputs. The compounded effects of lack of credit and unavailability of fertilizers conspire to delay the onset of the cropping season still further. So, "SONADER created a Union among the farmers' cooperatives to manage the scheme as a whole, including the finances," explains Moctar. "The money paid to SONADER (*redevance*) for scheme maintenance is kept in a bank account, to which the regional director of SONADER and the president of the farmers' union have equal access." It remains to be seen how effective the union will be in helping to manage these funds.

What of the future?

Thanks to the careful inclusion of farming-practices research into the project, WARDA and its partners have been able to give short-term advice (recommendations) to the rice farmers at Foum Gleita, and have thereby gained the good reputation of being the first researchers to visit the site and to have come back with some useful information—remember how skeptical the farmers were in 1998? This now gives us the opportunity to use the site for longer-term strategic research on soil-degradation processes associated with alkalinization—an opportunity we would otherwise not have had. Salt and water monitoring equip-

SONADER no longer has financial resources for automatic mechanical weeding. The use of herbicides or emptying (drying) the canals is not possible as the water is also used for domestic purposes. The few farmers who can swim are paid to manually weed the canals. The *tipha* is cut just below the water line—vigorous regrowth means that the measures normally only last for a short period (few weeks/months).

The Sourou Valley—The other half of the DFID project

Foum Gleita comprises only half of the WARDA–DFID soil-degradation project. The other half is based in the Sourou Valley in Burkina Faso. Soma Etienne Barro is a soil scientist based at the Farako-Bâ station of the *Institut de l'environnement et des recherches agricoles* (INERA), and is principal contact for the project in Burkina. "The first rice scheme was established in the Sourou Valley in 1985," explains Barro, "when an area of 50 ha was brought 'on line'." INERA became involved in 1995/96, when the local extension service (*Authorité de Mise en Valeur de Vallée de Sourou*, AMVS) contacted them and WARDA because farmers were complaining of salinity problems, and abandoning fields— sounds familiar? By that time, some 3000 ha were under irrigation, and the majority of the abandoned fields were in the oldest blocks. Here in the Sourou, however, low productivity was associated with patchiness of rice performance in the field, and there were calcareous (calcite) nodules in the soil. "Even before the DFID project," Barro continues, "we were in contact with Marco Wopereis at WARDA." Together, they decided to monitor farmers' practices, with INERA taking the lead—the Sourou Valley is a long way from WARDA's Sahel Station, even after a flight into Burkina. "We identified a great diversity among farmers' practices," says Barro, "with very few adhering to local recommendations, and all short of optimal. We believed that this was sufficient to explain part of the yield loss we saw in the field, but the farmers disagreed with us both on the classification of their practices as 'sub-optimal' and on our belief that they contributed to the yield loss."

At the start of the project, the researchers looked at the pockets of low productivity in the farmers' fields. They found that some were highly calcareous (that is, rich in calcite) and some had drainage problems. "During a field visit, farmers asked us to find a solution," continues Barro, "but first we wanted to know their own experience." Farmers said that they achieved partial relief from the problem by applying organic matter to the fields, but this only lasted for one season; they also obtained short-term relief by removing the calcareous nodules. The objectives of the project at Sourou were effectively the same as those at Foum Gleita. "However, on the basis of the farmers' reports, we decided to conduct a series of organic-matter trials," says Barro. "We tested the effects of manure, compost and straw on both rice performance (yield) and soil chemistry." Both manure and compost improved crop yields, but straw had virtually no effect. "There are two possible explanations for the effect of manure and compost. First, they may be altering soil chemistry, and enabling the binding of carbonates, so that they no longer create an alkalinity problem. Or second, they are simply providing nutrients that the plants can take up." Plant and soil samples are being analyzed, but "we suspect that there may be some nutrient-deficiency problem, possibly either zinc or phosphate." Piet van Asten favors the former option, "it seems very unlikely that phosphate is a problem," he says, "as all rice farmers in Burkina already apply adequate amounts of phosphate fertilizer to their crops, so I guess we will find that zinc is limiting here."

Unproductive patches are common in farmers' fields in the Sourou Valley. They may be associated with calcareous deposits and/or drainage problems. The higher productivity near the field bunds is an indication of a possible nutrient-deficiency problem—plants near bunds suffer less competition for nutrients

Other preliminary work included finding and interpreting old soil maps of the valley for possible clues; sampling of water from irrigation and drainage canals and wells for analysis; sampling of soils from productive and unproductive pockets in farmers' fields; and rapid EM38 salinity testing. So far, there is no clear salinity problem. Both water and soil are slightly alkaline, however, suggesting a similar problem to that in Foum Gleita, and the possibility of longer-term soil degradation. "If this is a nutrient-deficiency problem," says Barro, "is it that there are not enough nutrients in the soil, or are such nutrients being blocked by, for example, alkalinity?"

Samples from soil profiles (to monitor changes in soils with depth) have revealed increasing concentrations of calcareous nodules below 30 cm. These nodules have hard centers, and are soft on the outside—but whether they are dissolving in the soil to release carbonates and increase alkalinity, or whether they are being deposited by precipitation of calcite from the soil is as yet unclear.

Other problems are abundant in the Sourou Valley soils—for example, nematodes—but these do not seem to be related to the unproductive pockets. Farmers complain about the abundance of earthworms, which pile soil up at the base of the rice plants and reduce tillering. A pathological survey found a lot of plant disease, but again nothing specifically associated with the pockets.

Nutrient-omission trials are being started in 2000 to run for at least two seasons, especially to look at the role of phosphate and zinc fertilizers, but also including a treatment with nematicide. Monitoring of farmers' practices will continue, and the earthworm situation will be monitored and assessed. "Maybe in the next year, we will start to test the water and salt balances, and install piezometers to monitor the changes in groundwater depth," concludes Barro.

Moctar Ould Isselmou (second from left) and Soma Etienne Barro (third from left) look at screened trials at WARDA's Sahel Station with Marco Wopereis (left) and Piet van Asten (right)

ment is now in place in various fields (on both 'good' and 'problem' soils) and water quality is monitored throughout the scheme by SONADER, which has installed a small laboratory there, paid for by project funds. "We need about one more year to gather data on groundwater quality and water and salt movements," explains Piet van Asten, Dutch associate soil scientist handling most of the WARDA end of the DFID project, "and then we will move into modeling to determine just how important the alkalinization process is likely to be at Foum Gleita in the long term." Thus, with continued good-will from both farmers and SONADER, there is still the possibility of using Foum Gleita as a field laboratory for what might happen elsewhere.

The original plan was for the scheme to cover a total of 3600 hectares. The knowledge gained to date through the DFID project—that shallow soils are most affected by degradation—will serve as an important guideline for the positioning of further irrigation infrastructure once any such expansion goes ahead.

"This year (2000), SONADER will help the Foum Gleita farmers' union to work together with the Kaédi and Boghé unions to buy inputs (certified seed, phosphate and urea fertilizers) in bulk," says a positive-looking Moctar. "This should enable the farmers to have their inputs both cheaply and well before the start of the wet-season campaign."