Integrated Plant Nutrition Management in Mali

Summary Report 1998-2004

By Mamadou Doumbia, Abou Berthe, and Jens B. Aune

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<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIDEB</td>
<td>Association pour le développement du cercle de Bafoulabé</td>
</tr>
<tr>
<td>CFA F</td>
<td>CFA Franc (currency used in West Africa)</td>
</tr>
<tr>
<td>CMDT</td>
<td>Malian textile Industry</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>IPNM</td>
<td>Integrated Plant Nutrition Management</td>
</tr>
<tr>
<td>OADS</td>
<td>Organisation d’Appui pour le Développement au Sahel</td>
</tr>
<tr>
<td>PNT</td>
<td>Phosphate Naturel de Telemsi</td>
</tr>
<tr>
<td>ROCAM</td>
<td>Renforcement Organisationnel Crédit et Aménagement dans le cercle de Macina</td>
</tr>
<tr>
<td>VCR</td>
<td>Value Cost Ratio</td>
</tr>
</tbody>
</table>
SUMMARY

The objective of the project was to improve food security by building the competence of farmers and NGOs in soil fertility management. The project was implemented in Macina and Koro/Bankass in collaboration with CARE, in Bafaloubé in collaboration with AIDEB and in Gossi in collaboration with OADS. The project focused on four different technologies: microdosing of fertiliser, composting, zai method for water harvesting and urea treatment of straw. In each village the farmers selected one test farmer for each of the technologies to be evaluated.

The results of this study make it necessary to reconsider soil fertility management under Sahelian conditions. The study shows that it is possible to intensify millet and sorghum production in the Sahel using only minor investments in fertilisers. Sorghum and millet yield increased by 42 and 55% percent respectively when 0.3 g fertiliser was added together with the seeds to each planting pocket. This corresponds to about 7.5 kg fertiliser/ha and 3 kg fertiliser/ha for sorghum and millet respectively. In sorghum, each money unit invested in fertiliser gave a return from 7 to 12 money units using this fertiliser application method. In millet, each money unit invested in fertiliser gave an average return of 5 m money units. This technique is appealing to the farmers because of its low financial risk, the limited funds needed and the low workload. The method recommended by ICRISAT to apply 6 g fertiliser per pocket was not profitable for the farmers.

Composting has been well adopted in the town of Macina, but also in smaller villages. Women are using compost in gardening. Enriching the compost with Natural Phosphate from Telemsi (Phosphate Naturel de Telemsi – PNT) has further increased the quality of the compost. Composting in gardening is very likely to continue, but can be expanded to more villages.

Urea treatment of straw has been found to be interesting for improving feed quality for traction animals at the time of land preparation. Many farmers purchase cottoncake to feed the animals during this part of the season. However, urea treatment of straw is a cheaper alternative.

The zai method has been found to be appropriate for rehabilitating degraded land. According to farmers’ estimations, it takes about 40 man-days to treat one hectare. In sorghum, yields increased from 757 kg/ha in treatments without the zai to 1528 kg /ha with the zai method.

Farmer to farmer visits within and between villages, field days, regional workshops and radio-diffusions were used to scale-up the results from the study. Village IPNM committees have been established in many villages and one regional IPNM committee has been established in Macina. These committees organise visits to demonstration sites, collect demands for fertiliser and organise the purchase of fertiliser. Many villages approached the NGOs on their own initiative to join the project.

Adoption of the technologies can be best studied on the basis of what the farmers are actually doing. The IPNM committees registered a demand for 450 sacs of fertiliser in 2004, but access to fertiliser was very difficult because of the political crisis in the Ivory Coast. Despite this, many farmers were able to get hold of fertiliser in small quantities and apply it on their farm.
1. BACKGROUND

Soil fertility is an issue of national concern in African countries where the agricultural sector often represent as much as 50% of the gross domestic product (GDP). Soil fertility management therefore also plays a central role in the poverty reduction plan (PRSP) for Mali. Research in Mali has shown that at least 40 to 60% of the harvest is attained by using nutrients that are not renewed (Van der Pol, 1992). Depletion of nutrients is therefore an issue of national importance. In Mali it has also been found that in areas with more than 400 mm of rainfall plant nutrient supply is a more limiting factor to plant growth than rainfall (Penning de Vries and Djitèye 1982).

Problems of low soil fertility in Mali are caused by the following factors:
- The natural low fertility and the fragility of most soils of Mali (Poulain, 1976; Piéri, 1989; Doumbia et al., 1993)
- Use of organic and inorganic fertilisers lower than recommended (Piéri, 1989; Berckmoes et al., 1989; Van der Pol, 1992; Kieft et al., 1994)
- Reduction in fallow periods (Hoefsloot et al., 1993)
- Removal of crop residues (Van der Pol, 1992)
- Clearing and cultivation of marginal lands (Van der Pol et Giraudy, 1993) and limited use of soil conservation measures (Kieft et al., 1994)

At the national level, economic losses due to soil degradation in Mali were estimated to be 1,38 billions of F CFA, which represents 0,6% of the GDP in 1988. These losses will reach 9.3 billions of F CFA in year 2005 (Bishop et Allen, 1989; Kieft et al., 1994) if appropriate measures are not defined and applied.

As livestock densities are often high in drylands, it is easily assumed that animal manure is available in sufficient quantities to meet plant nutrient demand. However, the quality of manure is highly variable, depending on the quality of the feed and the way the manure is collected, stored and applied. Research conducted in Niger shows that manure production from the national livestock herd can only supply about 25 % of the nutrients needed to replace the lost nutrients of a modest pearl millet harvest of 0,4 ton per ha taken as a national level (Williams et al. 1995). Sandford (1989) has estimated that 16 to 47 ha of grazing land per hectare of cropped land were required to produce sufficient amounts of manure for sustaining a maize yield of 1 to 3 t per ha in a semi-arid environment in West Africa. These findings show that manure can at best be considered a supplement to other sources of nutrients.

Phosphorus is, together with nitrogen, the nutrient, which most frequently is limiting to plant growth in sub-Sahara Africa. Phosphorus often becomes a limiting factor because 60 % of this nutrient is removed with the harvested product if the stover is retained in the field (Sanchez et al. 1997). It is therefore impossible to rely only on recycling plant residues for the supply of Phosphorous.

Soil fertility problems are not only an agronomic issue, but are also strongly related to economical and social issues. Poor farmers are typically risk averse and cannot afford to make...
large investments in relation to fertility management. This study takes farmers’ socio-economic conditions as a point of departure and seeks to develop soil fertility management options that are feasible for poor farmers. Gender issues were also addressed.

1.1 OBJECTIVES

The overall objective of this project was to improve food security by building the competence of farmers and NGOs in soil fertility management.

The project did not only study soil fertility management from a technical/agronomic point of view, but also considered soil fertility management in a wider perspective including economical, social, institutional and environmental considerations.

The specific objectives of the project were defined as follows:

- Improve soil fertility and thereby increase millet and sorghum yields
- Improve nutrition of animals
- Rehabilitation of degraded land
- Assess the IPNM technologies from an economic, social and environmental point of view
- Build farmers’ own ability to develop new technologies
- Build organisational skills related to the introduction of IPNM technologies

1.2 THE IPNM APPROACH

The project has been built on the concept of integrated plant nutrition management (IPNM). IPNM is an approach to soil fertility management that combines organic and mineral methods of soil fertilization with physical and biological measures for soil and water conservation (Donovan and Casey 1998). IPNM adopts a holistic approach to plant nutrient management by considering the totality of the farm resources that can be used as plant nutrients. It is based on the following principles:

- Optimise the use of organic material
- Ensure access to inorganic fertiliser and improve the efficiency of its use
- Minimize losses of plant nutrients

Project villages were chosen in consultation with the NGOs and based on several criteria. In the ROCAM project the following criteria were used: (i) socio-economic structures of CARE-MALI such as ‘credit funds’, ‘cereal bank’, etc. must be available, (ii) the experience of the village related to soil and crop management technologies such as fertiliser management, ‘improved seeds’, live fences, etc., and (iii) the appointment of an agent of CARE-MALI to the village. In Bafalaoubé similar criteria were used. In 2003 the project initiated work in Koro/Bankass and in Gossi.

The average annual rainfall in the sites where the study was conducted was for Macina, Koro, Bafaloubé and Gossi approximately 600, 600, 800 and 200 mm respectively.

1 ROCAM- Renforcement Organisationnel Crédit et Aménagement dans le cercle de Macina
A diagnostic survey was initially undertaken to identify farmers’ constraints related to agricultural development and to understand their priorities and solutions to the problems they are facing. A wealth ranking was classified the farmers into different groups. This enabled the project to identify technologies suitable for the different wealth groups.

An important component of the IPNM project has been the appointment of an IPNM committee in the villages where the project was undertaken. The farmers themselves appointed this committee. This was given particular emphasis in the project areas where CARE was operating. The farmers also appointed a responsible person for the project in each village.

The objectives of this committee were as follows:

- Introduce the technologies to other farmers in the village
- Organise visits between the villages
- Develop an approach for how to get access to inputs
- Establish contact with suppliers of input
- Mobilise credit for input

The farmers in consultation with the development agents of the NGOs and the researchers selected the technologies that were appropriate for the sites. In some villages all the technologies were tested while in other villages farmers only chose to work on some of the technologies. The farmers themselves selected the farmers to take part in the test. Each of the selected farmers tested one technology. The test farmers had the responsibility to inform and share with the others their experiences. In the first year, only the test farmers took part, but in the following years many other farmers started using the technologies on their own initiative. Farmers from neighbouring villages were invited to see the test and this promoted the spread of the technologies.

At the end of each season, the IPNM committee identified the demand for fertiliser in the village and presented this demand to the NGO. As the project developed, the intention was that the IPNM committee should take the responsibility for purchasing and transporting the input to the village.

Before initiating the on-farm testing of the technologies, the development agents of the NGOs involved also received training on how to use and present the different technologies to the farmers.

Several methods were used for scaling up the technologies. The inter village visits and annual workshops were used to mobilise people and create interest for the project and to share experiences with the farmers. Radio programmes were used in Macina to inform farmers in villages outside CARE’s area of intervention. A national workshop on the project was organised in 2002 to discuss the results of the project with other NGOs, public development agencies, Malien researchers and the commercial sector. The researchers have also presented the project to the leadership of the Institute of Rural Economy (Institut d’Economie Rurale), Permanent Secretary of the Ministry of Agriculture, Secretariat of the Desertification Convention and SASAKAWA GLOBAL 2000.
1.3 THE IPNM TECHNOLOGIES

The technologies that were proposed to farmers were technologies that can be implemented at a low cost and at the same time can significantly contribute to raise productivity. The technologies were chosen based on the results from the diagnosis (chapter 3). The project focused on the following technologies:

- Micro-dosing of fertiliser in pearl millet and sorghum
- Improving water availability and yield by the zai method (mini water catchments);
- Composing by manure, crop residues and household waste. The quality of the compost was improved by Telemisi phosphate rock (PNT)
- Improving the quality of cereal straw (rice, millet and sorghum) by treating the straw with urea.

One of the key constraints raised by the farmers was low soil fertility and declining millet and sorghum yields. To address this problem, microdosing of fertiliser was proposed. This technology is characterised by the application of a small amount of fertiliser in the planting hole at sowing. One farmer (Lamine) in Boungou Marka in Macina was already using this technology in 1998. Another constraint identified by the farmers was the weakness of the traction animals at the time of land preparation. This causes delayed sowing and many farmers are purchasing cottoncake at a high price in order to supply feed with sufficient energy. The microdose technology will make more straw available, but untreated straw can hardly provide maintenance energy for the animal. There is not sufficient energy to provide energy for work. Urea treatment of straw was proposed to address the problem of weak traction animals at the beginning of the rainy season. Urea treatment increases the digestibility and nitrogen content of the straw. Urea treatment of straw was therefore proposed as an alternative to the purchase of cotton cake.

Use of composting is another method to increase soil fertility. Due to the high transport cost of compost, the easiest is to apply compost in gardens that are located close to the homestead. Microdosing of fertiliser will make more organic material available for composting, and urea treatment of straw will increase the quality of the manure produced, as the quality of the manure is highly dependent on the quality of the feed. Urea treatment of straw will in addition increase stall-feeding time and thereby improve access to manure. The compost produced can both be used for gardening or in relation to the zai method.

The zai method was introduced in the study to address the problems related to high run-off rate and soil degradation. The zai is a hole in the ground that is dug with a hoe to retain water. The zai method is appropriate for silty soils that have crusting problems. Compost or farmyard manure can be added to this hole to increase soil fertility. There are therefore synergies between the zai method and composting.
As described above there are considerable synergies between the technologies. This can promote adoption and make the technologies more interesting from an economic point of view.

1.3.1 Microdosing of fertiliser
Three different treatments were tested:

1. Farmers method (control without fertiliser);
2. 0.3 g fertiliser per pocket. This method consists of mixing seeds and fertiliser in a ratio of 1:1 before planting. This is equivalent to 3 kg fertiliser/ha in Koro/Bankass where there are about 10000 plants per hectare and 7.5 kg fertiliser/ha in Macina and Bafaloubé where there are about 25 000 plants per hectare.
3. Point application of fertiliser of 6 g of fertiliser per pocket. Di-ammonium phosphate was used in 2000 in Bafaloubé. In 2001, 2002 and 2003 the fertiliser NPK 15-15-15 containing 15 % nitrogen, 15 % phosphorous and 15 potassium was used in all sites.

The plot size for each treatment was 50 x 50 meters. There were no replications farmer’s fields and in the statistical analysis each farmer was considered a replicate. Each farmer sowed the treatments the same day. In Macina the pearl millet variety Toroniou was used. Sorghum was the crop used in Bafaloubé. The other farming operations were according to the farmer’s regular practice.
1.3.2 Urea treatment of cereal straw and multinutritional blocks

Urea treatment of straw makes the straw more digestible and increases its nitrogen concentration. The voluntary intake of straw will also be increased.

This method consists of treating straw with water containing 5 % urea. 50 litres of the liquid containing urea was added to each 100 kg of straw. The treated straw is sealed with a plastic sheet and then left undisturbed for 20 to 30 days. Thereafter, the straw is dried in open air for three hours before being given to animals. About 7 kg of straw per day can be given to oxen of about 250 kg life weight.

In Gossi there is not much straw available for urea treatment. Preparation of multinutrient blocks was demonstrated here in addition to the urea treatment. The multinutrients blocks was made out of 10 % clay, 5 % lime, 15 % cement, 20 % molasses, 30 % millet bran, 10 % salt, 10 % urea and 35 % water. These ingredients were mixed to produce the multinutritional blocks. The clay, water and lime were first mixed. Another mixture consisted of molasse, cement, salt and urea. These two components were mixed and the millet bran added. The multinutritional blocks needs to be dried for 5-7 days before it can be used. The multinutritional blocks will also increases digestion of low quality straw by stimulating rumen activity.
1.3.3 The zai method
The objective of this method is land rehabilitation and yield increase of pearl millet and sorghum.

The treatments tested were:

1. Farmers traditional method (control),
2. The zai method.

The zai is a hole in the ground 15-20 cm deep and with a diameter of 30-40 cm. The spacing between the zai is about 75 cm within and between rows. Approximately 200-500 g compost is added to each zai in order to improve the chemical and the physical characteristics of the rooting zone. Each treatment was tested on a plot of 20 x 10 (m). The treatments were sown the same day.

Observations were made on plant vigour, number of harvested plants and yield.

1.3.4 Compost making
The farmers were shown how to make compost using household waste, animal manure and straw. About 540 kg of organic material and 60 kg Phosphate rock of Telemsi (PNT) (10% PNT) was added to each compost pit. The compost was made during the dry season and composting time was from 4 to 6 months.
3. CONSTRAINTS AND OPPORTUNITIES IDENTIFIED BY THE FARMERS

3.1 MACINA

The household study and the PRA study showed that the farmers in the project areas have serious problems to meet their food requirements. The farmers stated that their own cereal production only lasts for an average period of 6 months and they also reported that the yields were gradually declining. Men and women ranked their problems related to agricultural production differently. The men ranked constraints leading to food insecurity and environmental problems in the following order of importance:

1. insufficient flooding of the plains,
2. insufficient farm equipment: oxen and plough,
3. insufficient animal nutrition, (iv) insufficient credit funds,
4. low soil fertility, (vi) insufficient road infrastructure and,
5. increasing soil erosion.

The women ranked their problems in the following order of importance:

1. insufficient credit funds,
2. problems related to gardening: seed availability, seed storage, and pests and,
3. low fertility of soils.

It appears from this assessment that different actions are needed if both women and men are to be targeted. The survey showed that gardening activities are more of interest for the women. Insufficient flooding of food plains is a problem in communities that are dependent on rice production, but this problem was not dealt with since it was addressed in the ROCAM project. When farmers were asked for reasons for low soil fertility, they proposed reduced length of fallow period, low biomass production due to erratic rainfall, limited use of organic fertiliser and no use of mineral fertiliser. To solve these problems the farmers proposed to transport household waste to the field, application of farm yard manure, composting, use of mineral fertilisers, increased plantation of Acia albida, use of leguminous plants in crop rotations and establishment of live fences. It appears from these answers that the farmers in general have a good knowledgebase with regard to which the fertility practices available.

3.2 BAFALOUBÉ

Farmers in the circle of Bafaloubé listed many of the same reasons for the low food security as the farmers in Macina. They listed the following reasons in decreasing order of importance:

1. insufficiency in farm equipment: oxen, plough, and cart,
2. low soil fertility, and
3. insufficiency or unavailability of arable lands.

According to local men and women, factors responsible for the low fertility of soils include:

1. population growth and its impact on reducing land availability, frequency and length of fallow periods,
2. limited availability and use of organic fertilisers,
3. unavailability and no use of mineral sources of fertilisers, and
4. increased soil erosion. In Bafaloubé no mineral fertiliser was available on the local market when the project was initiated.

3.3 YIELD EFFECTS OF MICRODOSING OF FERTILISER

Microdosing of fertiliser was tested both in sorghum and pearl millet.

The effect of microdose fertiliser application in sorghum was tested for 3 years in 33 on-farm experiments in the county of Bafaloubé (Table 1). There was a clear effect of fertiliser application on sorghum yield in all years. Yield increase over control was in average 42 % for the 0.3 g fertiliser treatment and 71 % for 6 g fertiliser treatment. Average yield increase over control in the 0.3 g treatment was 269 kg, which corresponds to 36 kg of grain per kg of fertiliser applied. In the 6 g treatment the yield increase over control was 454 kg/ha corresponding to 3 kg of grain per kg of fertiliser. These results were statistically significant in all years and across years. The years 2001 and 2002 were dry years showing that microfertilising is applicable even in dry years.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>832</td>
<td>538</td>
<td>538</td>
<td>636</td>
</tr>
<tr>
<td>0.3 g fertiliser per pocket</td>
<td>1112</td>
<td>819</td>
<td>787</td>
<td>905</td>
</tr>
<tr>
<td>6 g fertiliser per pocket</td>
<td>1531</td>
<td>938</td>
<td>801</td>
<td>1090</td>
</tr>
<tr>
<td>Average</td>
<td>1158</td>
<td>765</td>
<td>709</td>
<td>877</td>
</tr>
</tbody>
</table>

The effect of microdosing of fertiliser in millet was measured over 2 years and in 27 different experiments. The yield results in pearl millet gave similar results as in sorghum in Bafaloubé, but the yield levels were lower in millet as compared to sorghum. Average yield increase over control in millet when 6 g fertiliser was added was 133 % while average yield increase with the 0.3 g treatment was 56 %. Yield increase over control in the treatment where 6 g fertiliser was applied was 2 kg grain per kg fertiliser while the yield increase over control in the 0.3 g treatment was 23 kg grain per kg fertiliser.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2001</th>
<th>2003</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>210</td>
<td>228</td>
<td>219</td>
</tr>
<tr>
<td>0.3 g fertiliser per pocket</td>
<td>311</td>
<td>371</td>
<td>341</td>
</tr>
<tr>
<td>6 g fertiliser per pocket</td>
<td>469</td>
<td>556</td>
<td>513</td>
</tr>
<tr>
<td>Average</td>
<td>330</td>
<td>385</td>
<td>358</td>
</tr>
</tbody>
</table>

Table 2: Fertiliser in pearl millet

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Macina 2001</th>
<th>Koro 2003</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>210</td>
<td>228</td>
<td>219</td>
</tr>
<tr>
<td>0.3 g fertiliser per pocket</td>
<td>311</td>
<td>371</td>
<td>341</td>
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<tr>
<td>6 g fertiliser per pocket</td>
<td>469</td>
<td>556</td>
<td>513</td>
</tr>
<tr>
<td>Average</td>
<td>330</td>
<td>385</td>
<td>358</td>
</tr>
</tbody>
</table>

Significance: P<0.01, P<0.001, Ns
Nbr. of experiments: 19, 8
The economic performance of the different treatments was assessed based on the Value Cost Ratio (VCR) that measures the value of the yield increase due to fertiliser as compared to the value of the fertiliser used.

\[
VCR = \frac{(kg \ yield \ increase \times \ price \ per \ kg \ grain)}{(kg \ fertiliser \ used \times \ price \ per \ kg \ fertiliser)} \times \frac{yield \ increase \ per \ kg \ fertiliser}{kg \ yield \ increase \ per \ grain}
\]

A VCR of one implies that one CFA spent on fertiliser gives a return of one CFA. The VCR should be above 3-4 if the method is to be economically interesting for the farmers. The VCR showed that the method of applying 6 g fertiliser per pocket is not economically interesting for farmers as the VCR was below one in 4 out of 5 cases. However, the 0.3 g treatment is very interesting for the farmers as this method gave a VCR above 3 in all the 5 cases. These results question the recommendation given by ICRISAT that 6 g fertiliser NPK 15-15-15 should be given in millet (ICRISAT 1999, ICRISAT 2004). Yield increase over control by applying 6 g fertiliser was in the order of 52 to 134 % in Niger. The economic analysis from Mali shows that it is much more economically attractive for the farmers to use the 0.3 g fertiliser per pocket than applying 6 g fertiliser per pocket.

Table 3: Value cost ratio for the treatments (compared to the control without fertiliser)

<table>
<thead>
<tr>
<th>Species</th>
<th>Sorghum</th>
<th>Millet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site</td>
<td>Bafal.</td>
<td>Bafal.</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>2001</td>
</tr>
<tr>
<td>0.3 g fertiliser</td>
<td>9.33</td>
<td>9.37</td>
</tr>
<tr>
<td>6 g fertiliser</td>
<td>1.17</td>
<td>0.67</td>
</tr>
</tbody>
</table>

3.4 TIME USE AND FERTILISER APPLICATION

Estimations of time use of the different technologies were provided in meetings with groups of farmers in three villages (Table 4). These estimations varied, but mean time to sow one hectare of land in the 0.3 g treatment was 5 man-hours as compared to 14.6 man-hours for the 6 g fertiliser method. Interviews with the farmers in the other village confirmed that time use more than doubled when the 6 g fertiliser method was compared to the 0.3 treatment. The reason for this increase in application time is that one more person is needed to apply the fertiliser when 6 g fertiliser per pocket is applied. In addition, about 150 kg fertiliser/ha will be applied to the field in the 6 g method as compared to only about 7.5 kg fertiliser/ha in the 0.3 g fertiliser treatment. This increased quantity needs to be carried to the field and this increases farmers’ workload. According to the farmers, sowing seeds and fertiliser in the mix treatment (0.3 g) do not increase application time as compared to the traditional sowing method.
Table 4: Time use in man-hours per hectare for the different treatment and sites

<table>
<thead>
<tr>
<th>Site</th>
<th>0.3 g fertiliser pocket</th>
<th>6 g fertiliser pocket</th>
</tr>
</thead>
<tbody>
<tr>
<td>Souley</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Boungou Marka</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Kationo</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Mean</td>
<td>5</td>
<td>14.6</td>
</tr>
</tbody>
</table>

3.5 FARMERS’ AND RESEARCHERS’ FIELD OBSERVATION OF THE MICRODOSE TECHNOLOGY

The farmers made a lot of interesting observations in relation to the on-farm-experiments. One of the observations was as previously discussed the increased sowing time when applying the 6 g treatment as compared to the treatment where the seed and fertiliser are mixed (0.3 g fertiliser) This is very crucial for the farmers and is probably the main reason why many prefer the 0.3 g treatment. As seen in table 4, one person can at the maximum sow about 2 hectares per day when using the 0.3 g treatment while he can sow considerably less than 1 ha if he is applying the 6 g treatment. Rainfall in the Sahel occurs in showers and it is very important to sow as much land as possible shortly after a rain shower because the soils will dry up very fast. One farmer in the survey had 17 ha of land with millet and for this farmer it would be very difficult to assure timely sowing if the 6 g method were used.

In 2000 di-ammonium phosphate (DAP) was used as fertiliser while in the other years NPK 15-15-15 was used. It appeared that DAP burned the plants when 6 g fertiliser was applied if there was a drought after sowing. This effect was also to some degree visible in the 0.3 g fertiliser treatment. A burning effect was also observed when using NPK fertiliser, but this effect was much less pronounced. There was therefore a tendency that the plant looked stunted when the 6 g fertiliser was applied if a drought occurred after sowing, but this delay was quickly equalized and the plants receiving 6 g fertiliser developed faster and more vigorously than in the other treatments. However, this rapid development and more vigorous growth made the plants more exposed to end-of-season droughts, as evapotranspiration would be higher from plants that are growing vigorously as compared to plants with limited growth. There would therefore be a tendency that all measures that increase nutrient supply would make the plants more exposed to drought. However, it must be stated that even in dry years, the fertiliser treatments outperformed the control treatments.

Application of fertiliser made the plant considerably more tolerant to attack of the parasitic weed striga. It is previously known that measures that increase the fertility of the soil will also increase the plant’s resistance to striga. In Koro in 2004, farmers stated that they were able to harvest in striga infected soils because they practiced the 0.3 g fertiliser treatment.

Use of 6 g fertiliser per pocket as compared to mixing seeds and fertiliser (0.3 g fertiliser) entails a much higher financial risk. Crop failures are common in the Sahel due to drought, striga, bird attacks, locust and other pests and diseases. A harvest can therefore not be guaranteed. In addition, the farmers are financially constrained and are very exposed to shocks. Applying 6 g fertiliser per hectare gives a financial outlay of 39000 CFA per hectare if using the fertiliser
prices in 2004 while the 0.3 g treatment will only give an outlay of 2600 CFA per hectare. An outlay of 39000 CFA per hectare will be beyond the reach for the majority of the farmers in Mali, particularly if no access to credit is available.

One advantage of fertiliser application is that more straw will be produced and this increase can be relatively higher than the increase in grain production. Straw is a very important fodder source particularly at the end of the rainy season when there are few alternative fodder resources.

One farmer also noted that the same amount of production can be obtained by cultivating a smaller land size when fertilisers are used.

Some farmers in Bafaloubé have also been experimenting with mechanization of the microdose technology on their own initiative and without any support from the project. They have modified the disc in the sowing machine in order to sow seed and fertiliser simultaneously. This is particularly important in Bafaloubé since mechanisation is more widespread there than in the other sites of the project. They claimed that this change was successful.

Table 5 summarises the advantages and disadvantages of the two different microdose technologies.

<table>
<thead>
<tr>
<th>0.3 g fertiliser per pocket (seeds and fertiliser 1:1)</th>
<th>6 g fertiliser per pocket</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor effect on germination if drought after sowing</td>
<td>Burning effect on plants if drought after sowing</td>
</tr>
<tr>
<td>Lower yield than 6 g fertiliser</td>
<td>Highest yield</td>
</tr>
<tr>
<td>Lower labour demand than 6 g fertiliser</td>
<td>Higher labour demand than 0.3g treatment</td>
</tr>
<tr>
<td>Sowing on time</td>
<td>Delayed sowing</td>
</tr>
<tr>
<td>Low financial risk</td>
<td>High financial risk</td>
</tr>
<tr>
<td>Plant slightly exposed to drought</td>
<td>Plant exposed to drought</td>
</tr>
<tr>
<td>Increase straw availability</td>
<td>Much increase in straw availability</td>
</tr>
<tr>
<td>More resistant to striga</td>
<td>More resistant to striga</td>
</tr>
<tr>
<td>Less land needed to obtain the same production</td>
<td>Less land needed to obtain the same production</td>
</tr>
<tr>
<td>Can be mechanised</td>
<td>Mechanisation difficult</td>
</tr>
<tr>
<td>Feasible for poor farmers</td>
<td>Not feasible for poor farmers</td>
</tr>
</tbody>
</table>

3.6 ZAI METHOD

The zai method is used for reclaiming degraded land, harvesting water and increasing yield. The pits increase infiltration of water and the compost added to the soil increases supply of plant nutrient and improve rooting conditions for the plants. The zai method was tested in 34 on-farm experiments. The effect of the zai on productivity was clearly visible and convincing to the farmers. In some plots no yield was harvested on plots not treated with the zai while a good harvest was produced on land treated with the zai. In all sites and years there was a clear effect of
the zai treatment. In sorghum in Bafaloubé, yield increased by 80% and 168% in 2000 and 2002 respectively while in millet yields increased by 83% in 2001 and by 111% in 2003. The zai method is probably more applicable in Bafaloubé compared to Macina and Koro because crust-forming soils are more common in Bafaloubé. Bafaloubé has silty soils that are particularly vulnerable to crusting. The riverbanks in Bafaloubé are especially suited for the zai method.

| Table 6: Effects on the zai method on sorghum and millet yield |
|---------------------------------|---------------|---------------|---------------|---------------|
| Treatment                    | Sorghum       |                | Millet        |                |
| Control                       | 968           | 566           | 785           | 368           | 576           |
| Zai                           | 1739          | 1517          | 1442          | 778           | 1110          |
| Significance                  | P<0.001       | P<0.01        | n.s.          | P<0.1         | n.s.          |
| Nbr. of experiments           | 8             | 3             | 14            | 9             |

In Bafaloubé it was estimated that it takes about 40 man-days to treat one hectare of land with the zai treatment. Average yield increase across two years in Bafaloubé was 861 kg/ha that corresponds to 22 kg of grain per day of work. This is equivalent to a return of 1100 CFA per day using a grain price of 50 CFA per kg. In pearl millet, the average yield increase was 534 kg/ha, which is equivalent to 13.6 kg of grain per day of work. This economic output is interesting for the farmers. The zai will not have to be redone every year; it can last for 2 to 3 years.

Despite these good yield results with the zai method farmers are concerned about the labour demand. They will always assess which activity will give the best return to their work.

3.7 COMPOSTING

Composting is a particularly interesting approach in relation to gardening. Most of the composting activities have been undertaken with female gardeners in Macina. In 2001, the estimated production was 20 tones. In 2002, 127 women and 22 men in Macina practiced this method. Each participant produced in average 1.5 m$^3$. This approach has become very interesting for many households in the town of Macina, but also in other smaller villages as seen in table 7.
Table 7: Involvement of women in IPNM, especially phosphate rock composting.

<table>
<thead>
<tr>
<th>Villages</th>
<th>Number of composts ‘men’</th>
<th>Number of composts ‘women’</th>
<th>Volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangou Marka</td>
<td>1</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td>Fiah</td>
<td>1</td>
<td>8</td>
<td>68,5</td>
</tr>
<tr>
<td>Fing</td>
<td>3</td>
<td>13</td>
<td>46,5</td>
</tr>
<tr>
<td>Folomana</td>
<td>1</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>Founou</td>
<td>5</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>Gan</td>
<td>1</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Macina</td>
<td>2</td>
<td>65</td>
<td>120</td>
</tr>
<tr>
<td>Mangoni</td>
<td>3</td>
<td>41</td>
<td>88,5</td>
</tr>
<tr>
<td>Saye</td>
<td>1</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>Sokoua</td>
<td>4</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>127</td>
<td>484,5</td>
</tr>
</tbody>
</table>

The women are especially using compost on onion as this crop has a good price and gives a good return to the application of compost. The onion bulbs also grow bigger when the compost is applied. The women also observed that compost enriched with Natural Phosphate from Telemsi (PNT) gave a better yield than the simple compost. There were also less problems with weeds when compost was used as compared to when manure was used. The composting process kill the weeds because of the heat produced. The women complained that it is difficult to find sufficient organic material to produce the compost. Manure is for sale in the village and one donkey load is sold at 1000 CFA.

The gardens for the women are located in plots of Office du Niger. Each parcel is about 0.07 ha.

Access to PNT has now become more difficult because it is no longer produced in Bourem north of Gao. However, 50 kg sacs of PNT can still be purchased at 4000 CFA. The PNT will enrich the compost because of its phosphorous content. The PNT enriched compost contains about 10% PNT. Each ton of compost contains 100 kg of PNT with a value of 8000 CFA. The effect of the compost enriched with PNT can last for several years. The PNT was given free to the farmers in all years.

The yield effect of composting was tested in sorghum and millet.

Table 8: Effect of compost on grain yield (kg/ha) Bafaloubé and Macina 2001

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Sorghum Bafaloubé</th>
<th>Millet Macina</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>624</td>
<td>360</td>
</tr>
<tr>
<td>Compost</td>
<td>844</td>
<td></td>
</tr>
<tr>
<td>Enriched compost</td>
<td>1027</td>
<td>1902</td>
</tr>
<tr>
<td>Significance</td>
<td>P&lt;0.01</td>
<td>P&lt;0.01</td>
</tr>
<tr>
<td>Nbr. experiments</td>
<td>12</td>
<td>4</td>
</tr>
</tbody>
</table>
3.8 **UREA TREATMENT OF STRAW AND MULTINUTRITIONAL BLOCKS**

Lack of fodder for traction animals was identified as a problem by the farmers in the diagnosis in Macina. In Bafaloubé access to fodder is easier because of the lower livestock density and more rainfall. The project therefore gave a particular emphasis on urea treatment of straw in Macina, but the technology was also demonstrated in Macina. Multinutritional blocks were only demonstrated in Gossi. An assessment of this technology is not available.

Farmers practiced the urea treatment in pits covered by a plastic sheet. Farmers experienced that it took some days for the animals to get used to urea treated straw. They realized that it is important to leave the straw in open air for some hours before giving it to the animals so that the unpleasant smell can disappear. About 50 traction animals have been fed using urea treatment of straw in the Macina area.

Number of participating farmers was 22 and 20 in 2001 and 2002 respectively. In both years about 6 ton of urea treated straw was produced. The animals were in average partly fed on urea treated straw for 38 days. Urea treatment of straw therefore increased the time the animals spent in the kraal, making more manure available.

The farmers observed that animals that were fed with urea treated straw performed better than traction animals having received no supplementary feeding. Animals are often so weak that they cannot do any work before they are given supplementary feed. Some farmers are therefore purchasing cottoncake as fodder. The farmers observed that the animals given urea treated straw were in a better condition and worked for longer hours than the animals given cottoncake. It was observed that some traction animals given cottoncake started shivering after having worked for some hours.
4. FARMERS CONSTRAINTS AND ADOPTION OF TECHNOLOGIES

It is always difficult to assess farmer’s adoption of a new technology. In 2000 and 2001 fertiliser was given for free to the farmers while in 2002 they paid 50% of the price. In 2003 they paid the full price of the fertiliser. In the first years it is therefore not possible to assess adoption because of the strong subsidies. Figure 1 shows the number of villages participating in the program. The majority of the villages participated on their own initiative without being asked by any of the NGOs to join the program.

![Figure 4: Number of village involved in the project](image)

The farmers stated that the method of applying 0.3 g fertiliser per pocket is the technology that interests them the most. The reason is that they can apply this technology on large areas and that it will have a clear effect on production. The adoption of the other technologies is site specific. Composting has been very well adopted in the town of Macina whereas the zai is used by the farmers for rehabilitation of degraded land in Bafaloubé, Macina and Koro. Urea treatment of straw has only been introduced in Macina and to some extent in Gossi. The evaluation in 2004 showed that the use of urea treatment is constrained by access to fertiliser.

The following constraints have been identified as important for the adoption of the new technology:

- access to fertiliser
- lack of credit to purchase fertiliser
- establishment of contact between farmers and credit institutions
- technical know-how of the technologies
- timely arrival of inputs
- pest and diseases
- free roaming animals

Different methods must be used to assess farmers’ adoption of technologies. Individual and group meetings with farmers give some answers, but it provides more insight to study what the farmers
are actually doing. The evaluation in 2004 revealed that the farmers are facing many constraints related to the adoption of the technologies. In 2004 there was a national crisis with the supply of fertiliser in Mali. This was probably partly related to the political crisis in the Ivory Coast since Ivory Coast has been a major supplier of fertiliser in Mali. For the majority of the farmers use of fertiliser was a new technology. They were aware of the effect, but they had limited experience with the use of this technology. Use of fertiliser will require a market oriented approach. In many cases they cannot operate as individuals because that makes purchase of fertilisers too expensive. Each village has to operate as a group and identify how much fertilisers the village needs, collect the money, establish contact with the dealers of fertiliser, transport the fertiliser to the village, store the fertiliser and distribute it in village. All this requires organizational skills that cannot be built in one year. The NGO CARE seems to have been particularly strong in building organizational skills and has emphasised this by working with the farmers. Adoption therefore seems to be higher in the CARE project areas in Macina and Koro than in Bafaloubé and Gossi.

It has also been difficult for the farmer groups to establish contact with the suppliers of fertiliser and to build trust with them. In many areas where the project has been implemented there has been no previous commercialization of fertiliser and to develop a market of sufficient size is a challenging task. CMDT (Compagnie Malienne de Développement du Textile/ Malian Company of Textile Development) has previously supplied fertiliser to many villages in Macina, but this practice has now ceased, as CMDT is no longer involved in the distribution of fertiliser. Access to credit has also been a difficult issue for the farmers. It appears that the farmers in Macina have not clearly seen the relationship between the credit schemes that exist in many of the villages and the potential this offers for purchasing fertiliser. Another issue that appeared in some areas was that free roaming animals damaged the crop. In the rainy season the animals are normally herded, but free roaming animals occur. Striga and pests and diseases may also cause problems. If farmers spend money on fertilisers, it becomes important that the farmers control weeds, pests and diseases otherwise the investment in fertiliser is foregone. This appeared to be a particular problem in Bafaloubé where weed invasion of the fields was more common due to higher rainfall.

Despite these constraints it appears that the farmers have partly adopted the technologies. It is surprising to note the widespread adoption in Koro even though the project has only been running for two years in this site. In Macina the adoption has been slower and particularly constrained in 2004 due to poor access to fertiliser.

In Koro, many farmers in the Forêt de Segué (Forest of Segué) have started to adopt the technology. They bought packages of one kg of fertiliser in the market in Koro in 2004. Originally the villages in Koro had planned to use the microdose technology on a large scale. They had collected money to purchase 250 sacs of DAP (di-ammonium phosphate) which were intended to be used in 13 villages Koro. The money was presented to the CARE representative in Koro, but he refused to accept it because he knew it would be difficult for him to find fertiliser in the market. The farmers thereafter went to Mopti to purchase fertiliser, but failed to find any fertiliser in the market. As an alternative they chose to buy fertiliser in small quantities on the market in Koro. In Bankass, the farmers in the workshop stated that they would like to continue with the microdose technology even without the support of the project.
In Macina the GINV committees in the different villages in 2004 collected demands from the farmers who were interested in purchasing fertiliser. The regional GINV committee then collected the order from the village GINV committees. In total the regional GINV committee received an order for 300 sacs of fertiliser. However, the committee was not able to find any fertiliser on the market. Another problem was that the committee thought that the dealer of fertiliser would give them fertiliser on credit. This was a wrong assumption and it turned out that it was impossible for them to purchase any fertiliser on credit. Despite the failure of the centralised demand, farmers were able to find fertiliser in small quantities on the market and in some of the villages this functioned in a satisfactory way. For example one farmer in Boungou Marka in Macina was able to sow 7 ha of the 1:1 seed /fertiliser microdose technology (0.3 g fertiliser treatment). In this village there was also a demand for 100 sacs of fertiliser. It appears that in this village there was a group of farmers that was strongly interested in the technology, and this interest was also spilling over to the other farmers in the village and neighbouring villages. In other villages it was also found that innovative farmers could motivate others to use the IPNM technologies. This was the case for villages like Founa and Say. It appears that farmers that have practiced the technology for 3-4 years are continuing to use the technology even though the supply of fertiliser was difficult in 2004. The GINV committees are still intact and the committees stated that they would also organise the demand for 2005.

It appears to be clear that the microdose technology in Macina has generated considerable interest. At the beginning, the project focused on 7 villages where the CARE extension agents were located. Farmers from neighbouring village saw the results in the microdose demonstration sites and these villages asked CARE to join the program. In 2002 there were 23 “voluntary villages”. The CARE project phased out in 2003, but there are still GINV committees in many of the villages. In 2002, more than 120 hectares were sown with the microdose technology.

It is worth noting that new farmers have started to use and test the technology in 2004 in Macina even though there has been no support or push from CARE or any national NGOs.

Access, in terms of both availability and funding, was identified as one of the key constraints limiting fertiliser use in each of the project areas (Macina, Bafaloubé, Koro, and Gossi). To overcome this constraint, the IPNM program has brought together, through annual workshops, farmers, technical agents, input and product dealers, and local authorities. As a result of such actions and increased demands, four fertiliser outlets have recently opened in Macina and one in Bafaloubé. In addition, retails of fertiliser are more often seen in rural, weekly markets of the Macina areas. Some of these retails existed before the IPNM program, but have more than doubled with the increased fertiliser demand due to the IPNM program.

Outlets in Macina can supply a few bags of urea and DAP (total of 5 to 10 bags). Fertiliser is sold in cash. These outlets will only provide bigger quantities if ordered and paid (about 50%) in advance. These outlets are not yet ready to accept ‘loan programs’ which consist of giving fertilisers to the farmer at the beginning of the rainy season and being paid back in the form of rice or millet at the end of the season. Retails in rural markets are limited to bags of 1 to 5 kg of urea, DAP, and cereal blend which are also sold in cash.

Contacts have developed with IPNM Committees and Commission of the Macina area with fertiliser dealers such as COMADIS, SOMAFERT, PROFEBA, and Abdoulaye GUINDO.
Unfortunately, none of these dealers were able to provide the needed fertiliser on a loan basis. It is suggested that the farmers use the existing credit schemes developed by CARE in the villages.

Private radio stations have become key communication instruments in Mali in the past 10 years particularly in rural areas. Radio programs were used to further promote IPNM technologies. Local radio was always invited to cover both regional and local annual evaluation workshops. Farmers from surrounding villages were through these radio programs informed about the IPNM technologies. As a result of these radio reports, villages not originally part of the program have approached CARE/AIDEB projects for more information about IPNM.

Weekly ‘IPNM messages’ were often organized by CARE and test-farmers, IPN Committees, and visiting farmers to discuss advantages, limitations and implementation of IPNM technologies. These encouraged exchange of experience, as some farmers ‘came out’ to the radio to provide further explanations.

Radio messages were also used to invite input dealers.
5. LESSONS LEARNED

There are several important lessons that can be drawn from this project related to agronomic, economic and social issues.

One important lesson is that farmers can very quickly adopt a technology if they see a benefit from it. This was the case in Koro where a farmer started to adopt the microdosing of fertiliser technology only after one year of demonstration. It has previously been taught that fertiliser is not feasible under sahelian conditions because of the risks involved, but the method of adding only 0.3 g fertiliser per pocket is appealing to the farmers because of the low risk and limited capital required.

The farmer’s demonstrations have been very important for the adoption of the new technologies. Other farmers have seen the demonstrations and have discussed the results with farmers practicing the technologies. What other farmers say appears to be more convincing than what the researchers and extension agents say.

Backling from the NGOs has been very important for the success of the project. At the beginning of the project CARE staff was rather sceptical to the approach, but after having seen the result in the field and talked to farmers, a very strong backing was given by CARE both financially and technically. In Bafaloubé, the AIDEB project provided good backing in the beginning, but financial problems made AIDEB reduce the scale of their operations from 2003 and onwards. The adoption of the technology therefore seems to be less in Bafaloubé. The AIDEB project has now received new funding and the work previously undertaken is a good basis for continuing the work. The OADS project has also been financially constrained and they have to a lesser degree been able to keep up and develop the work with their own resources. Because of the distance to Gossi, it has also been more difficult to follow up the work even though the technologies have been demonstrated. It appears therefore that backing from the NGOs has been crucial for the uptake of technologies.

The annual workshops that have been organised at the sites have been very important in relation to the sharing of information and building a team spirit in the project. From 40 to 102 participants took part in these workshops for each zone. The presentations by the farmers have been in focus at these workshops. These workshops have planned the actions to be undertaken in the coming year. These workshops have therefore been important for the development of the village committee and regional committee for IPNM.

One of the lessons learned is that organisational skills are very important for the success of the project. This work is not yet done as it takes time to develop these skills. Approaching the market actors is also a learning experience for the farmers and it takes time to understand how to deal with the economic actors in an appropriate way.
6. ENVIRONMENTAL IMPACT

IPNM technologies have an impact through their effect on nutrient mining, soil erosion, building of soil organic matter, sequestration of carbon and reduction of household waste.

Water erosion is an important problem on silty soil in Mali. The zai method has been found to be an efficient way to reduce erosion problems and rehabilitate degraded lands.

The microdosing of fertiliser and the zai method increase sorghum and millet yields. The roots systems of the plants will grow bigger and this root system contributes to building soil organic matter. This improves the quality of the soil, but will also contribute to sequestering carbon from the atmosphere.

Composting can also contribute to cleaning up the village, since all the organic waste can be put into the composting pit. This will reduce breeding grounds for pests and diseases and the homestead will be cleaner. This effect is already visible in Macina.

7. SECONDARY EFFECTS OF THE PROJECTS

In addition to the primary effects of the project related to yields and farmers' adoptions there have been planned and un-planed secondary effects of the project. These effects must be considered as spin-offs from the project.

The most important secondary effect of the project is that many of the components of the GINV project will be implemented in a new CARE funded project in many communes in the Ségou region. A new project funded through CARE will also be initiated in Koro/Bankass, Banjagara and Djenne and this project may also include IPNM components.

A Ph.D study has also been initiated as a result of the project. Adama Coulibaly is studying microfertilising and mechanisation of the pocket application technology. His interest in the subject originated from participating in the initial phase of the IPNM project. He is registered for PhD at the University of Bamako.

A Norwegian M.Sc. student at the University of Life Sciences in Ås has studied microfertilising in Northern parts of Burkina Faso. Her thesis work was also inspired by the IPNM work in Mali.

Training has also been an important component of the IPNM project. The development agents of CARE, AIDEB and OADS have been introduced to the concept of IPNM and the approach on how to work with the farmers. Other NGOs have also been introduced to the approach through the workshop that was organised in 2002.

The Institute of Rural Economy (IER) is using the microdose technology in a project on carbon sequestration in Mali.
The results of the project have also been presented at the ICRISAT seminar in Niamey in 2003 and at the conference on sustainable development in Stockholm in 2005. The results of the project were also presented at the UD/Noragric seminar in Oslo in 2004.

8. RECOMMENDATIONS

This study forces us to rethink soil fertility management in the Sahel. The study shows that it is possible to intensify millet and sorghum production in the Sahel using only minor investments in fertiliser. Current recommendations from ICRISAT do not seem to be economically profitable for farmers. The method of mixing seed and fertiliser in a ratio of 1:1 (0.3 g fertiliser pocket) that corresponds to about 7.5 kg of fertiliser per ha has proved to be very interesting for the farmers and the risks involved are very moderate since so low quantities of fertiliser are used. It appeared that this low quantity of fertiliser is also profitable even in dry years. This methodology should be scaled up to a large scale in the sahelian environment. However, such a process will not take place without a backing from national development agencies, NGOs, the commercial sector and research institutions.

Organic matter management needs to be given due consideration in the future. Increased emphasis should be given to recycling parts of the crop residues. Retention of crop residues is important for maintaining soil organic matter, reducing surface temperature, reducing crusting, and infiltration of more water and trap dust that is rich in nutrients during the sandstorms. Increased recycling of organic matter cannot be achieved without a change in the grazing system.

Urea treatment of straw has been found to be interesting in order to feed traction animals at the beginning of the rainy season. However, this technology should also be introduced to female farmers. Urea treatment of straw can be used for fattening of sheep and goats for national and religious celebrations. During these times meat has a good price.

Building new IPNM committees and strengthening existing ones should be a key focus in the coming years. Building such viable IPNM committees takes time, as the organisational skills are often limited in the villages.
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Drylands Coordination Group Addresses in Norway:

**Secretariat of the Drylands Coordination Group**
Grensen 9b, 0159 Oslo, Norway
Tel : +47 23 10 94 90, Fax : +47 23 10 94 94
e-mail : dcg@drylands-group.org

**ADRA Norge**
Akersgata 74, 0180 Oslo, Norway
Tel: +47  22 11 20 80, Fax: +47  22 20 53 27
e-mail:  102555.2157@compuserve.com

**CARE Norge**
Universitetsg. 12, 0164 Oslo, Norway
Tel: +47  22 20 39 30, Fax: +47  22 20 39 36
e-mail:  care.norge@online.no

**Development Fund**
Grensen 9b, 0159 Oslo, Norway
Tel: +47  23 10 96 00, Fax: +47  23 10 96 01
e-mail:  u-fondet@u-fondet.no

**Norwegian Church Aid**
P.O. Box 4544 Torshov, 0404 Oslo, Norway
Tel: +47  22 22 22 99, Fax: + 47  22 24 20 24
e-mail:  nca-oslo@sn.no

**Norwegian People’s Aid**
P.O. Box 8844 Youngstorg, 0028 Oslo, Norway
Tel: + 47  22 03 77 00, Fax: + 47  22 17 70 82
e-mail:  norsk.folkehjelp@npaid.no

**Noragric, Department for International Environment and Development Studies**
University of Life Sciences, P.O. Box 5003, 1432 Ås, Norway
Tel: +47 64 94 99 50, Fax: +47 64 94 07 60
e-mail:  noragric@noragric.umb.no