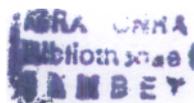




Institut Senegalais de Recherches Agricoles



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**Theme : Improving and Sustaining Food and Raw Material production in West Africa :
Reversing Soil Acidification, Loss of Organic matter, and Erosive Runoff in Food Production
Systems.**



Proceeding of the Workshop of the West Group : Cape Verde, Gambia, Mali and Senegal

January 11 - 14 th 1999 | Kaolack Senegal

By Aminata Niane Badiane

With the collaboration of Mateugue Diack and Mamadou Khouma

January 2001

Natural Resource Management INTERCRSP

**Improving and sustaining Food and Raw Material production in West
Africa : Reversing Soil Acidification, Loss of Organic Matter, and
Erosive Runoff in Food production Systems**

**West group:
Cape verde, Gambia
Mali, and Senegal**

*Proceedings of the West Group Workshop
January 11-14th 1999, Kaolack Senegal (W. Africa)*

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Foreword

This workshop is a realization of a long term effort supported by the USAID African Bureau, The many Collaborative Research Support Programs (CRSPs), The Institute du Sahel (INSAH), and more importantly the individual research organizations of each of the member countries in the InterCRSP project. As such each of these organizations and their directors and scientists should be proud of bringing together and sharing of their best thoughts and suggestions to address the severe food security, low income, and sustainability challenges faced by sub-Saharan agriculture today.

The InterCRSP efforts represent an attempt to take the best technologies of the CRSPs and, in fact, from anywhere in the world to address these challenges.

As will be apparent in the papers, there is some cause for optimism, although farmers are using extremely low levels of nutrient fertilizers, they seem well aware of the value of fertilizer and the need for it. They just seem unable to purchase it at least for the subsistence crops of sorghum and millet. Fertilizer use on irrigated rice, cotton, and maize is profitable and use on these crops is growing. Experience in The Gambia shows that even the subsistence farmers respond quickly to changes in fertilizer prices, unfortunately, dramatically higher costs due to recent structural adjustments have resulted in drastic reductions in fertilizers use. While fertilizer use is extremely low in Mali, it is apparent that IER scientists are aware of the issues and are pursuing a number of initiatives to improve the policy environment. While there are some technical adjustments to increase yield and efficiency of fertilizer use under study by the InterCRSP project, it is apparent that much of the deficit in fertilizer use relates to policy and economic issues. One of the interesting initiatives underway in Senegal is the government subsidized application of rock phosphate and probably more importantly of phosphogypsum, a heretofore unwanted waste product that has great value in restoring nutrients and reversing a portion of the widely recognized nutrient mining taking place in sub-Saharan Africa. Other countries in the tropics have recently noted the value of this resource and it has become a standard commercial practice in the acid, low fertility soils of Brazil.

As will become apparent in the scope of presented papers, studies on nutrient management predominate at this stage of the project. This represents a strong underlying concern throughout the project for the severe nutrient mining that is gradually reducing both crop yields but also production potential. We expect this theme to be joined with new studies on water and soil conservation and more economic evaluation and analyses as their role becomes more apparent and the proper studies and personnel are identified.

We note that among the papers presented some of the first studies of impact of nutrient management on village water supplies have been conducted. Based on the initial results, it seems that fertilizer application rates are so low that there was little increase in nitrate concentrations of village drinking water wells. We caution that the results are preliminary, however, and the situation may be completely different in urban margins where prices of vegetables are so high that exorbitant amounts of physical labor and fertilizer are applied to meet the demand. With the extremely sandy soils, highly intensive agriculture, and shallow water tables, nitrate contamination of groundwater remains a concern and needs further study.

Lastly, we must thank the Institut Senegalais de Recherches Agricoles, and the personnel of the Kaolack Experiment Station for both organizing and hosting this first workshop, and also for assembling these proceedings into such a useful document.

This **has**, indeed, been an **exemplary** workshop **and** we would **like** to **thank** the Coordinator Dr. Aminata Badiane **and her** staff and colleagues for providing **such** a **high** standard for **subsequent** workshops.

Russell Yost
Feb. 28, 1999

Opening Speech by the Director General of ISRA

Dear Representative of INSAH,
 Dear Director General of NARI,
 Dear Coordinator of the West InterCRSP Group,
 Dear Participants,

It is a pleasure for me to be here with you for the first workshop of the Western group of InterCRSP which include Cape Verde, the Gambia, Mali and Senegal.

I need to welcome you first in Senegal, particularly in Kaolack, the capital city of the Peanut Basin.

I would take this opportunity to extend to you my greetings for the New Year. The collaborative research project, whose data will be reviewed during this workshop, is very important to us. In fact, restoring and increasing the productive capacity of soils in Sub-Saharan Africa, especially in West Africa, are key components to promoting a sustainable agriculture in this region.

The objectives sought by this collaborative research project, combating soil acidification, loss of organic matter, losses due to soil erosion, and their impact on production systems, should bring a significant contribution to increasing food production in West Africa.

It is very comforting to notice that these objectives are major components clearly defined in the strategic workplan of ISRA. The implementation of this workplan starts this year.

The strategic workplan of ISRA (1999-2003) is the first phase of the implementation of the enterprise project of TSRA. This project defines the major strategic orientations and options of ISRA for year 2015.

Dear participants,

ISBA, which is proud to host this workshop, is going through deep changes. In fact, the institute is now, by the vote of the Parliament, registered by the law on Scientific and Technologic Public Services, ('EPST').

In addition, the presidential act approving the organization and functioning of ISRA has been signed recently. Another presidential act on the establishing rules of ISRA will be signed very soon. In 1998, several procedures were adopted to allow an optimal functioning of the institute. There were procedures for scientific management managing research stations, accounting systems, etc. These changes should allow better management of new or ongoing projects such as this involving Cape Verde, the Gambia, Mali, Senegal, INSAH, Virginia Tech. and the University of Hawaii.

Dear participants,

During four days, you will review and screen activities implemented through the collaborative research program on soil, water and nutrient management. Based on your qualifications, I have no doubt that the recommendations from this workshop will improve the performance of this project.

With this hope, I declare open the first workshop of the West InterCRSP group

Restoring Natural Resources for Food Security and Income

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Abstract

One of the most serious constraints to food security in West Africa has been the steady decline in agricultural productivity per unit area. The decreasing productivity of the food production system in West Africa must be reversed in order to achieve food security and sustainable productivity. The InterCRSP/West project is dedicated to reversing this trend through improved management of the regions natural resources. One of the most important keys to the improved management is another resource – the human resources, that is the talent, experience, and dedication of key scientists of the region. The many similarities in problems, experiences with the problems, and the solutions to the problems form a knowledgebase of major value for the region. With such a knowledgebase, that which has been learned in some countries need not be relearned in others. We suggest that the exchange of this knowledge and the raising of conscientiousness of the scientists with these skills is one of the most promising and exciting ways to reverse the productivity decline. As a result of the first two years of research we identify the following activities as integral to our strategy to reverse the decline in productivity.

1. "Cross visits," the coordinated visits of a key, experienced scientists from one country to another and vice versa, are suggested as one of several methods to improve the use of knowledge and experience of scientists in all countries in the InterCRSP/West group. This may be a method to provide temporary expertise to initiate programs or to fill short-term or initial, exploratory research needs. A procedure is being developed to facilitate and improve this sharing of knowledge and skill.

2. Conservation of soil and water is needed more than ever. Major losses of water, soil, and nutrients routinely occur at present. Stone lines and various steps in their enhancement with multiple-use vegetation is being suggested and further tested as effective strategies to better utilize water before it is lost to runoff.

2. Nutrient management efficiency centers on animal manure and to meet this challenge a "manure extender" hypothesis is being tested. The technique seeks to enhance the effects of manure with inorganic fertilizers, particularly in sandy, poorly buffered soils. The technique is based on a current practice by farmers in the Dougouba village of Mali.

4. On-farm tests, based on a thorough, initial exploratory participatory appraisal, acquaints both the extension personnel, researchers, farmers, and the community to constraints and opportunities for improvement.

5. Current fertilizer and food pricing policy is not conducive to providing incentives and raw materials to producers to increase productivity. Research in Gambia shows that fertilizer use was reduced dramatically with price increases. On-farm studies indicate that the constraint is not the farmer's awareness of the need for nutrients but rather the policy governing its pricing and supply. While some technical improvements in

fertilizer efficiency appear possible with improved management of manure and fertilizers as suggested above, it is clear that nutrient use efficiencies are not as limiting as marketing and policy constraints.

1. Cross visits

Surely one of the most important of the resources of the West region of the InterCRSP effort and, indeed, all of the countries participating in the InterCRSP project, is the human resources represented therein. It is, therefore, one of the goals of this project to acquaint scientists of each institute with these potential resource persons and to develop a minimal cost protocol for financing the travel of these persons to assist other countries in their speciality. An example of a recent "cross visit" was the August visit of Dr. Mohamed Kebbeh, NARI, The Gambia to accompany a visit to the InterCRSP/Mali and the SM-CRSP/Mali experimental sites and subsequently to visit the InterCRSP/Senegal site. The purpose of this visit, from InterCRSP objectives, was to take advantage of the short term research that Dr. Kebbeh undertook while studying with John Sanders in Purdue University. Dr. Kebbeh provided a seminar while at IER/Mali and also gave a summary of his work while in Senegal. While the main purpose was to provide the results of the work in Pur-due with the model developed by Economist John Sanders, Dr. Kebbeh also had the opportunity to share some of his experiences with fertilizer availability, use, and cost policy in The Gambia. For example, Dr. Kebbeh pointed out that prior to structural adjustment the rate of application of chemical fertilizer to crops in The Gambia was one of the highest in Africa. After structural adjustment of the Gambian currency, fertilizer prices became quite high and did not come down with time. Fertilizer use has sharply dropped off reflecting the adverse "price of product" / "price of input" ratio. If the farmers are similarly responsive to fertilizer cost in other countries as they appear to be in The Gambia then it suggests a strong possibility that reducing fertilizer price may help in increasing fertilizer use, which seems imperative to reverse the nutrient mining that continues to erode the food production capacity and endanger food security.

Another example of cross visits is the expansion of soil and water conservation research in The Gambia. Under consideration is the possible cross visit of a Senegalese scientist with extensive experience in soil and water conservation in conditions of soil and climate very similar to those in some areas of The Gambia. Such sharing of expertise and building on past experience in quite similar conditions can accelerate progress and avoiding many years of costly experimentation.

Other examples of local expertise are apparent, but in many cases the presence of this expertise is not known and it can be difficult for home institutions to justify visits when they already have persons with job descriptions similar to those of the experts. Perhaps one of the difficulties is in recognizing the unique talents in various InterCRSP institutions and rewarding and stimulating that talent.

During the August 1998 visit to Kaolack, Senegal, this issue was discussed and a recommendation to the InterCRSP coordinators was formulated. We suggest that persons with the specific talent be identified and the minimal costs of travel (air ticket and per diem) be divided between the receiving institution and the InterCRSP/West project. The initial visit by Dr. Kebbeh was completely financed by the Project but this cannot be continued.

Several proposed "Cross visits" include:

1. Modou Sène visit to **The Gambia** to **assist** in **establishing** a soil **and** water conservation program in that **country**.

2. Modou Sène visit to Mali to assist in the improved **utilization** of stone **lines**, their vegetation, **stabilization**, and **preservation**. Also to **estimate costs** and **advisability** of locating water retention structures of **the** type developed by the **French NGO** near Fansirakouro.

3. Further visits by M. Kebbeh to Mali to update and **complete** a **survey** of **farmer** information that **suggests subsistence farmers** in the **Cinzana** region are, contrary to **expectations**, applying **chemical fertilizer** to their subsistence **crops** and how they are achieving **this**.

4. A visit by a **soil** and water conservationist to Cape **Verde** is **under** discussion.

5. A **sharing** of expertise on **phosphogypsum** (Badiane?) and rock phosphate (**Doumbia?**) is needed between Mali **and** Senegal.

“Cross visits” **can** be **useful from** the perspective of local **scientists** because it illustrates the broad **relevance** of their programs in others countries **and** the **interest** of **other countries** in those issues **and approaches**. Such visits **can** generate the necessary **enthusiasm** to stimulate **fresh approaches** and ideas to **solving** the age-old problems.

2. Soil and Water Conservation

One of the more **striking** observations of the agriculture in the OHVN (Upper Niger River Watershed) is the extreme drought that seems prevalent, **yet** as **much** as 800 mm of rain **is** received **annually**. **Also** noticeable are the steep slopes and **frequent exposure** of impermeable rock and **soil** -- the **result** of extensive surface **soil** erosion and **exposure** of hardened **underlying materials**. The **result** appears to be a major loss of **rainfall**, especially when large, intense **storms** occur. As a **result**, **it** is clear that major efforts in recovering and improved **utilization** of the **rain** are needed.

During the initial **visit** to the **Kati** region near Bamako, stone barriers were **seen** in Tourodo and Fansirakouro. These structures had been extremely **useful** in **slowing** water overflow and **accumulating rich**, but highly **erosive soil**. Others have noted that stone barriers are beneficial, but **often** their beneficial **effects** are **lost** when the **stones** are removed and reused for other purposes. **Also** stone **lines** are only effective in trapping **larger soil particles while dissolved** nutrients and organic **materials** continue to be **lost**. Consequently, alternatives are being developed including testing **species** of grasses or trees that **secure** the highly erosive **soil accumulated** behind the stone barriers, **lending some permanency** to the **practice** and **also provide** for forage, **timber**, and firewood. One species has been suggested for this **purpose**, *Guiera senegalensis*, but others have advantages depending on the location and household needs. Investigations of alternative species **include** testing **species** designed :for animal forage **selected** by the International Livestock Center in **Africa** (ILCA) being tested at Bamako, Mali. One **noteworthy species** is *Zizyphus mauritiaca* used both as a forage and for fruits that children relish. In addition, cropping options that capture **water** before it leaves the **field** are needed. Some **photos** of these technologies are available on the **InterCRSP** website: (http://agrss.sherman.hawaii.edu/yost/intercrsp/intercrsp2/Web_Technologies.htm).

In **some** villages large trees have been prematurely chopped down to produce timber necessary for **fencing** livestock. An alternative, living fences, are being tested at several villages. Svecies under test are *Jatropha spp.*, and *Zizyphus mucronata* (which

Another technology **that** substantially improves food security are small dams of **very** small **size** that retain water throughout **much** of the year. **Such** a water control structure was developed by the Association Volontaire du Progrès (a **French** NGO) in the **vicinity** of Fansirakouro, Mali. **This** structure maintains water throughout the dry season and has measurably increased **the** water table, both above and below the structure, **according** to the delighted villagers. The Fansirakouro farmers showed the structure to **InterCRSP** scientists requesting assistance in developing additional structures of a similar **design**. **Such** structures **could** be of use **in many** countries of the Sahel. **These** small structures, also **illustrated** at **the** above website, are currently under **study** for **adaptability** to wider **implementation** and use. The small structure **does** not appear to **require** extensive maintenance and thus should not **risk falling** into major disrepair. A **characterization** of these types of technologies will **occur after** the workshop with surveys by **IER/Mali** and Virginia **Tech** soil and **water** conservation engineer. **Experience** gained in Senegal is also thought to be of major use in improving **soil** and water conservation practice in the **InterCRSP/West** network (**Perez et al.**, 1997).

One of the major steps in preparing for improved **soil and** water conservation in Mali has been a brief survey of the **soils** of the **experimental** sites of Fansirakouro and N'tetekouro **carried out** by **LaboSEP** (Laboratoire de Sol, Eau, et Plante) of the Institut **d'Economie** Rurale (IER), **Mali** (Table 1).

Table 1. Survey of **soils** represented in on-farm experiments in N'tentoukouro and Fansirakouro, Mali, **LaboSEP**, IER, Mali.

Village	Soil location	Tentative Soil Taxonomy	Major features
Fansirakouro-1	400 m NE of the village	Petroferric Haplustult	Sandy, highly weathered soil, wet-dry season, rocky, very acid
Fansirakouro-2	2km W of the village	Typic Ustrocept	Clayey, nearly a vertisol, difficult to manage, highly alkaline
Fansirakouro-3	1km W of the village	Oxic Haplustult	Sandy, highly weathered soil, wet-dry season, very acid
N'tentoukouro	2 km NE of the village	Plinthic Haplustalf	Sandy, weathered soil, wet-dry season, acid, plinthite ¹ layer at 40-60 cm.

(Survey conducted by Omar Doumbia, IER)

¹A plinthite layer is **especially** critical as if exposed to **oxidizing** conditions and **allowed** to dry because it **can harden** into **stone forming** laterite. This **may** have occurred in some soils where **extreme** erosion has **exposed** the plinthite present in the lower horizons.

Soil and water conservation efforts have **been** underway in other InterCRSP/W countries, most notably **Senegal** and Cabo Verde. As **we'll** see **during** the workshop visit near Kaolack, **Senegal**, there are several examples of excellent water conservation efforts

in several watersheds of southern **Senegal**. Some of these results are **published** in Perez et al. (1997) and **describe** the following techniques.

1. Contour cultivation

2. Dry season de-compacting. This technique corresponds to a 10 cm deep subsoiling **done** by **animal** traction with a single excavating pick. Because there is no

available time **during** the **beginning** of the **rainy** season (seeding operations), it is the only solution to help infiltration of water **from** the **first**, and **often** violent rainstorms.

3. Shallow **ridging** before **emergence**, for a **groundnut crop**, sometimes **ridging soil over** a line of manure (Sène, 1995).

4. Shallow **earthing up**, for the **millet crop**. This **might** include covering manure with the ridged soil.

5. **Lastly**, brushwood **checkdams** and stone pavements were used to **stabilize** the main **gully** and transform **it** into a permanent waterway.

The extensive, steep slopes of Cape **Verde** present a **severe** challenge to all soil and water conservation efforts. However, **it is** clear that **much** effort has been invested in soil and water conservation. Some techniques implemented **include** **contour-hedge rows**, **planting** on the contour and vegetating **with** drought **resistant** species. Extensive work has been invested in **stabilizing** stream **channels**. It is clear **that** improved conservation of soil and water remain at the **core** of improved natural **resource** management in the **InterCSR/W project**. New, more effective conservation measures are needed while **existing** methods should be more widely disseminated.

3. Nutrient management efficiency

As numerous papers have **indicated**, **nutrient mining** and **nutrient** depletion are widespread in the **region** and probably are the **single** most important reason for the consistent **decline** in **crop productivity** of the **region**. The **InterCRSP/W project** is **working** on this problem **from** two perspectives and disciplines: **that** of the **policy** level and farm level economic **programming** and secondly by encouraging more estimates of the amount of **nutrient mining** by **encouraging** routine assessments of the **nutrient balance status** of all proposed or improved cropping systems.

Fertilizer pricing policy. The **analysis** at the **policy** level revolves **around** the **combined** work of Mohammed Kebbeh (The **Gambia**) and John Sanders (**Purdue University**) (Kebbeh, 1998). A farm-level **economic** programming model developed by Ousmane **Coulibaly** (1995) was adapted to **predict** conditions in The **Gambia** (Kebbeh, 1998). Not **surprisingly** a large number of **studies identify** the extensive **nutrient mining** as a result of **insufficient** fertilizer use, in some cases **caused** by unfavorably high **prices** of **fertilizer**. Van der Pol (1993), for example, estimates that 40% of the **farm income** is derived from mined nutrients. The factors directly leading to the **nutrient mining** and negative **nutrient** balances are thus **probably** not as **much agronomic** as **socioeconomic** and include **pricing policies** and the interaction of **pricing policies with** socioeconomic conditions which have reduced the use of **fertilization**. Before structural **adjustment**, fertilizer use in The Gambia was **among** the highest in Sub-Saharan Africa. After the adjustment and sharp **price** increases, **fertilizer** use has **fallen** to among the lowest in the **region**. The Coulibaly **model**, developed as part of a **Malian** student's thesis at **Purdue University**, replicates this observation, when adapted with coefficients representative of conditions in The Gambia. For example, Kebbeh (1998) illustrates that a 25% increase in fertilizer **price** is **predicted to result** in a nearly 4-fold **reduction** in fertilizer use. Further **studies** of the **fertilizer price** increase indicate that as **much** as 30% of the fertilizer **price** in The Gambia is **simply** due to taxes on imported **fertilizer materials**. It seems **unlikely** that those in charge of **shaping this policy** are cognizant of the extreme sensitivity of fertilizer use to **price fluctuation** and, in turn, probably are not aware of the extremely negative **effects** on sustainability and long **term productivity** of **Gambian agriculture** of this tax on imported fertilizer. Further analysis with current

data is needed to prepare a case for policy change to stimulate fertilizer use as a **basic component** of food security and **sustainability**.

The **Coulibaly** model appears likely to be **useful** in examining policy implications of **pricing** of fertilizers and **food products** in Mali as **well**. **Scientists** at the Institut D'Economie Rurale, Mali observe that the **current** ratio of price of grain **product** to price of fertilizer is so low that farmers **cannot and** should not be applying chemical fertilizers. For example, the ratio of the price of a kilogram of millet to the **cost** of a kilogram of urea N is **about 0.2**, which is **well** below the recommended value of 2 to 4 to expect adoption (**IFDC**, 1988). A participatory rural appraisal of farmers in the Cinzana region, however, revealed that 22% of the **farmers** interviewed said that they were, in **fact**, purchasing and applying **fertilizers** to millet (**SM-CRSP**, 1998). Two hypotheses **may explain** this unexpected purchase and application of **inorganic** fertilizer in face of **such** an unfavorable **benefit/cost** ratio:

- Millet is the staple **crop** in the Cinzana region and is an important source of **family** pride and food security. Being able to produce the staple food to nourish the family and **provide** for the household is obviously highly regarded. Thus the value of providing for one's **own family** is not reflected in **market** prices partially because this is a **subsistence** item and the availability of millet on the **market** is sporadic, usually only available when **crop** yields are **unusually** great and excesses occur (Kebbeh, personal communication, 1998). According to **this** hypothesis, the ratio **does** not **reflect** the true value of millet for the food security of the Cinzana household.

- The second **factor** might be technological, that is the **farmers** may be practicing a particularly **efficient** method of fertilizer application **such** that the **crop** response **per unit input** might be **much** larger than that assumed in calculating the **IFDC** ratio of 2 to 4. This **seems** to be the case at least with manure applications in the village of Dougouba, near **Cinzana**, Mali. A **common** practice of farmers in this region is to **localize** the application of **manure**. As will be discussed **later** regarding the "manure extender," there is some reason to expect **unusually efficient nutrient utilization** when inorganic fertilizers are physically mixed and **placed** with manure.

Further studies of the 22% of the farmers in the Cinzana region are needed to **confirm** this surprisingly **frequent** use of inorganic fertilizer in spite of low **market prices** for millet. Further studies are needed of the **Cinzana** (Sahelian **climate**) and the Bamako (Sudano-Sahelian **climate**) production systems using the **Coulibaly** model with updated **prices** and more accurate fertilizer response **functions**. With **further** analysis in **hand**, discussions and **seminars** with **policy-makers** is suggested as a next step to **bring** the results to the attention of the Ministry of Agriculture and other appropriate authorities in Mali. The **Gambian** example of sharply reduced **fertilizer** use in response to high **prices** tends to **validate** the dynamics and **predictions** of the **Coulibaly** model. It **remains** to be **seen** if reversing fertilizer **prices** will also reverse the decreases in fertilizer application **following** structural adjustment and restore the food production potential of **the** country.

The exercise of **analyzing** fertilizer use by **subsistence** farmers when **price/cost** ratios are less than 0.5 has illustrated the need for holistic assessments of the problems of food security and **productivity decline**. It has **also** illustrated the growing talent and experience of **scientists** in the region and their potential to **effect** change if efforts are **coordinated** and **conducted** in an interdisciplinary, collaborative fashion among the countries. This exercise has been a **powerful** example of the value and **enthusiasm** that can be **generated** with carefully selected and conducted cross-visits of experienced

scientists from one country to another. We have learned a great deal from the cross-visit and will be seeking to plan and organize a structure for such visits in the future.

Technology to improve the efficiency of fertilizer use.

Mi-mure extender

The "Manure extender" concept is an approach proposed by the InterCRSP/West project to realize the beneficial effects of inorganic fertilizer while building on an existing farmer practice of using animal manure. The objective of the approach is to extend the beneficial effect of manure by physically mixing manure and N, P, K inorganic fertilizer and incorporating it in a localized fashion in the crop row such that plants such as sorghum, millet, and peanut are placed at either end of the manure - N, P, K mixture placement. Some farmers in the Dougouba village, Cinzana, Mali., have been applying compost in such a localized fashion for several years so it may be relatively easy for them to adapt their current methods by adding mixed inorganic fertilizer to the manure.

This proposed method of application is thought to offer some potential benefits over the usual manure versus inorganic comparisons in which the manure and the inorganic fertilizer are physically separated:

1) The manure, when localized, should provide a higher CEC environment than the surrounding sandy soil (usually less than 5% clay), which might reduce the excessive amounts of nutrient in soil solution in such poorly buffered soil, and reduce damaging effects of excessive concentrations of nutrients, i.e. salt damage, and thus possibly reduce loss through excessive leaching downward of the nutrient cations.

2) The manure should provide a buffer against radical temperature and moisture change, because of the high moisture holding capacity of organic material and the high water content when at the same soil moisture tension as the surrounding soil. This should improve the growing environment of plant roots, increase the number of microorganisms to mineralize the organic material, and improve likelihood of inoculation and intensity of mycorrhizal colonization of plant roots.

3) The manure should provide a slow release of nutrients while the N, P, K provides soluble, immediately available nutrients.

4) The manure should provide the small amounts of micronutrients necessary to meet crop requirements. Although macronutrients such as N, P, K, Ca, Mg, and S are usually deficient, it is also quite likely that micronutrients are deficient in the extremely sandy soils.

Unfortunately, reliable tests of whether or not the "manure extender" idea really works have not yet been completed. Consequently, it remains an idea that may or may not work but seems to have some interesting advantages to manure or inorganic fertilizer alone.

Phosphogypsum

The use of phosphogypsum, heretofore, an unused waste product of the soluble phosphate fertilizer industry, is a direct method of adding calcium and sulfate, both of which are usually present in inadequate quantities. The importance of the calcium and sulfate in phosphogypsum becomes apparent when the high costs and low availability of alternative sources of calcium is known. Lime and rock phosphate are probably the only other major sources of calcium for the region. The practice of applying gypsum to acid soils is relatively a new practice, probably only really becoming a widespread commercial practice in Brazil in the 80's and 90's (IBRAFOS, 1992). During 1998 year the Senegalese government has begun a program of subsidizing the use of phosphogypsum and rock phosphate by encouraging 1/2 rock phosphate and 1/2

phosphogypsum application. It is unclear whether the excellent yields of peanut and millet in the peanut basin in 1998 are at all related to this new practice.

While some farmers seem to worry about the acidifying effects of phosphogypsum, it is useful to consider the extensive and widespread adoption of phosphogypsum together with limestone as a highly successful means to quickly remediate the surface and subsoil of acid soils of Brazil (IBRAFOS, 1992).

Rock phosphate continues to spark controversy as the residual benefits seem difficult to quantify in a manner that can be satisfactorily analyzed economically (Jomini et al., 1991), who found that for Niger the price of rock phosphate needs to be less than $\frac{1}{2}$ that of soluble phosphate in order for it to be a better choice. One unresolved issue appears to be that the residual effect of rock phosphate has not been well-quantified and whether the acidity neutralization and additions of calcium are significant. Considering the extremely high price of limestone, perhaps one of the few ways to stabilize acidity might be with the use of rock phosphate. On-going studies in Mali are eagerly awaited in which the effects of composting with rock phosphate seem to be a beneficial pre-processing of the rock phosphate. It is unclear at the present time how much of the beneficial effect might be due to the higher CEC of compost and thus maintaining low soil solution calcium driving the dissolution process, or whether the organic materials might be a source of acidity to accelerate the dissolution of the rock phosphate or whether the higher water capacity and higher water content of the organic media permits dissolution reactions to continue longer than in a sandy soil at the same soil moisture tension.

4. On-farm experiments

On-farm experiments are essential to both developing the appropriate technology as well as in testing and ensuring the adoption of the technology. The on-farm experiments conducted in Mali, for example, have been highly useful in better understanding the constraints to adoption of technologies that will mitigate nutrient mining, acidification, and in the conservation of both soil and water

The on-farm experiments in the villages of Fansirakouro and N'tetekouro revealed that the farmers are well-aware that fertilizers benefit crops. Farmers and extension agents were, not surprisingly, unfamiliar with experimental protocol and applied fertilizer treatments of manure and mixed fertilizers in a manner that precluded statistical comparison of treatments. One farmer, for example, applied the fertilizer only on the poor section of his field because he knew that it would likely improve crop growth and yield. This practice, of course, makes it impossible to compare treatments to estimate the effect of fertilizer. One of the main results, then, of the on-farm experiments was not the initial, intended purpose, rather it was an indication that the techniques and methods of efficient fertilizer and manure application are yet to be learned. Some fertilizers, for example, nitrogen is mostly applied after the initial planting and can be surface-applied, while: manures, phosphates, and liming materials including rock phosphates should almost always be applied and incorporated into root zone for efficient utilization. Another important observation was that most farmers had great difficulty obtaining the 2 tons / ha of manure required for even the small experimental area. This illustrates the scarcity of this nutrient source, the impossibility of supplying all nutrient needs by organic means alone and emphasizes the need for inorganic fertilizers to supply the nutrient needs and arrest nutrient mining.

Numerous problems were also encountered in non-nutrient factors that became confounded with treatment effects making it impossible to test the initial hypotheses of 'treatment effect. Examples of such **confounding** factors were heavy shading by trees and major variations in amount of gravel in the soils on which treatments were applied. Dates of **planting** for all treatments were not the same and treatments were applied differently. The treatments included four 'treatments: 1) A **control**, 2) 2 tons of animal manure, 3) 2 tons of animal manure + N, P, K, fertihzer, and 4) the N, P, K, fertilizer alone. The latter N, P, K treatment is necessary in order to test for the **presence** of a synergistic effect among the organic and inorganic fertilizers as hypothesized.

The results illustrate that farmers appear to be well aware what fertilizers are and that they **can** be beneficial. Improved efficiency of fertilizer use seems possible through improved placement, timing, and improved coordination of applications with plant growth and **nutrient** requirements. It seems prudent to **further** explore some of the **combined** effects of manure and mixed N, P, and K fertilizers as **suggested** above. The magnitude of change needed to reverse nutrient mining, however, **will** clearly require more than a simple agronomic improvement in fertilizer use efficiency. **Economic constraints** appear to be **much** more limiting and fertilizer pricing policy seems to be **one** of the key limiting factors to reversing nutrient mining and restoring productivity of the land.

5. Current food and fertilizer pricing policy

As pointed **out** in both a recent book and later publications, Sanders indicates that it is **finally accepted** that both **organic** and inorganic sources of nutrients **will** be required to reverse the nutrient mining affecting Sub-Saharan Africa (Sanders and Ahmed, 1998). Tbis is also the conclusion of a publication focused on nutrient management in **Africa** (Buresh et al., 1997).

It seems agreed that fertilizer pricing is **one** of the focal point of limited application of nutrients and price subsidies are advocated by Sanders and Ahmed (1998). **They** argue that progress towards reducing malnutrition, achievement of **greater food self-sufficiency**, and reduction in environmental degradation **can all** result from increased and improved fertilizer management.

These authors point out that there are synergistic effects between organic and inorganic nuttient sources and on the poorly buffered soils the **combined** application makes sense. Some of the reasons **given** above for the rationale for the "manure extender" idea are in agreement with Sanders' suggestions. The authors suggest that sub-saharan countries have been rationing foreign exchange and putting a low priority on fertilizer imports. Low input strategies involving mixed crop rotations and livestock, while **helpful**, are no longer sufficient to ensure positive nutrient-balance cropping systems, i.e. those systems that no longer use more nutrients than they contribute to the soil. These methods are complements to inorganic fertilizer rather than substitutes.

Sanders and Ahmed also point out that a national fertilizer strategy needs to include the revision of economic policy to emphasize the profitability of food production rather than focusing on maintaining low urban food prices. In the long run with improved technologies, opportunities, and incentives for farmers, food prices will likely lower. Lowering fertilizer prices seems, therefore, a way of permitting fat-mers to feed themselves and begins to take up their critical role in providing improved food and raw material not only for themselves but also for the entire society.

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Improving food production in rural areas of the Sahel: a review of potential technologies

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I. Anahory

Abstract

Due to increasing **number** of factors **affecting** its food production systems, the capacity to produce food in **Africa has been declining over** the past **decade**. To **further identify** and understand the most limiting **factors** to declining **crop** performance, the **InterCRSP/West** team conducted a survey in **October** of 1997 **across** four countries of the Sahel (**Cape Verde, Gambia, Mali and Senegal**). These countries are involved in a collaborative research program for improving and sustaining food and raw material production in Africa. The survey revealed that effective biomass management, water conservation strategies and **prices of farm products** limit the food producing capabilities of these countries. **Currently**, the dominant agricultural practice is **mixed farming** involving **crop** and **livestock**. Millet, sorghum and peanut are the main staple food **grown** by farmers. **Labor** availability is a major **concern** because of migration of youth to **cities**. In most **areas** tree density is **very** low due to **human** usage and high mortality **during** drought. Grass **cover** is also **dominated** by **annual** species. **Insufficient** land is available for **fallow**. **Manure** production is low because of **lack** of forages, which they attribute to low fertility of the soils, **decline** in **rainfall** and **lack** of fertilizers. Wind erosion and run-off have also reduced the production capacity of fragile soils

1. Introduction

A stable food supply **is** essential to the welfare of a society. In **most** of **West-Africa** food production per **capita** has **been** declining **over** the last **decades**. This has been **mainly** attributed to the rapid population growth and soil **fertility** depletion.

In the Sahel, increased soil **acidity** and erosion **along** with decreased soil organic **matter**, seem to be the major **constraints** to **food** production. Because **farmers** in the four countries visited are **all resource** poor **and** in view of the urgent nature of the **agricultural** problems, the greater impact on sustaining food production would be to determine technologies that **can** positively affect farming **activities**. This article will **briefly** review technologies that **may** significantly improve **small** farmer's production system.

2. Evaluating current technologies and their relevance to production systems in the Sahel

Crop Residue management

Crop residue management strategies **deserve special** attention in all four countries. At the **end** of the survey it **became** apparent despite their efforts, **current farming** practices are neither **feeding** the **people**, nor helping them emerge from poverty, while the degradation of the natural **resource** base continues. In the region, a **common** practice is to remove **crop** residue from the farm to be **sold**. This practice takes away nutrients that would have been available to plants for the next **growing**

season. Often, biomass capable of **restoring soil organic matter** leaves the **field** as fuelwood (Fig 1.) or as **crop** residues (fig.2).

Fig. 1. Biomass leaving the farm to the **city** as **fuelwood** (Fansikoro, Mali)

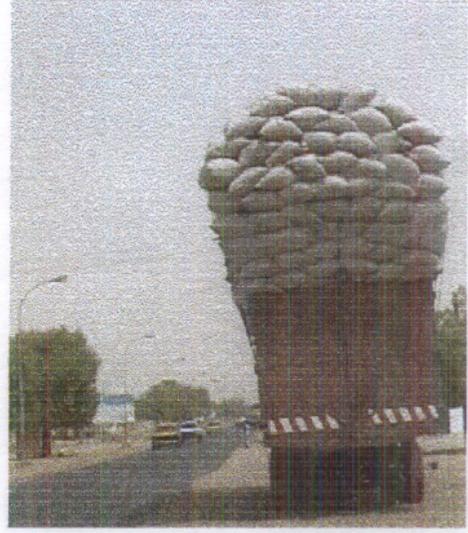


Fig.2. Biomass **leaving** the field as **crop** residues (Kaolack, Senegal)

Because field **often remain** bare between cropping seasons, soil **nutrient losses may** be accelerated by **runoff** and wind storms. In addition, the **removal** of trees and other types of vegetation on hilltops **often further** increases soil **nutrient losses during** rainstorm **events** (Fig.3 and Fig. 4).

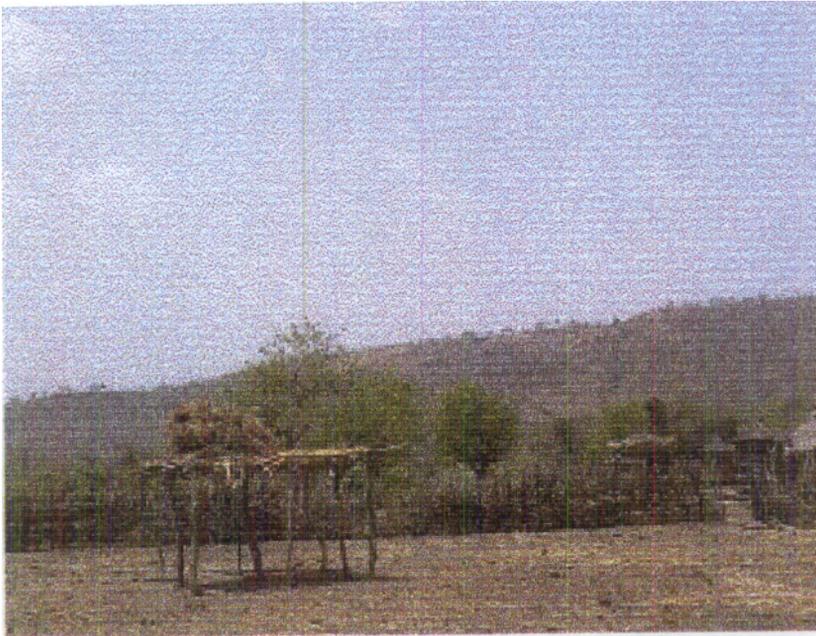


Fig.3. Hilltop vegetation **clearing** a potential source of erosion (Fansirakoro, Mali)



Fig.4. Typical aspect of a **farm after crop** harvest (Fansirakoro Mali)

Studies conducted elsewhere have **often** shown that substantial accumulation of **soil** organic **matter can** be achieved if crop residues are incorporated into the soil **after crop** harvest or **even left** on the **soil** surface as mulch. Furthermore, mulch **cover** is known to **enhance soil** biological **activity, modify** soil temperature, improve water conservation, reduce soil sealing and **crushing**, and reduce soil erosion (**Lal**, 1974; Padwick, 1983; **Sivakumar et al.**, 1992). Note that **Pieri** (1989) shows cases where the opposite occurs. In **fact**, in the **presence of manure (crop** residues), it appears that in addition of other factors not **yet known, fertilizer** management practices and **soil** texture **can** result in either gain or loss of **soil** organic **matter over time**.

Why biomass is not **left** on the **farm** is not well understood but the **lack** of water to

grow extra feeds for livestock during the long dry season can be singled out. Because most farmers lack the financial resources and/or cannot get access to farm credit to afford chemical fertilizer, without which the process of nutrient depletion will continue and become severe every year, the choice of crop residues seems to be an alternative that cannot be ignored.

Our hope is what the InterCRSP project puts a greater emphasis on finding ways to effectively manage crop residues. Already, experiments on crop production systems that take into account nutrient balance and soil water status over time are underway.

Green manure and cover crops

Conventional agricultural practices use chemical fertilizers to restore the nutrient status of impoverished soils. However, these fertilizers are costly and often cannot be purchased by rural small scale farmers of the Sahel. Under these conditions, the preservation of biomass in the form of green manure becomes an important mean to replenish soil fertility.

Before the wide spread use of chemical fertilizers in developed countries, green manure and cover crops in rotation with cereals were commonly used. The InterCRSP survey conducted in October 1997 revealed that green manuring is not used at all or on a limited basis in most of the region visited. However, evidence of many species (Fig. 5.) for organic green manuring exists (A. Berthe personal communication).

Sanchez et al., 1989 found that for short cycle crops, such as maize, rice and soybean that have high demand for nutrients, timely application of organic matter with low C/N ratio, such green manure and compost could synchronize nutrient release with plant demand. Thereby, minimizing the amount of inorganic fertilizer needed to sustain high crop yield. When plant species are properly selected green manure can enrich the soil with fixed N, conserve and recycle soil nutrients and provide ground cover that minimizes soil erosion.

Fig.5. Potential green manure species (Niebe trial at Cinzana Station, Mali)



Manuring and composting in Cape Verde, Gambia, Mali and Senegal our survey team found that the use of animal manure is strictly tied to livestock ownership as expected. Unless a farmer can afford animals he is unlikely to use manure, because his only source of animal manure will come from the animals. As a result, whenever a farmer is determined to become an animal owner, the tendency is to grow cash crop to the detriment of food crop. For the very poor, manure is not an option or its use is limited to fields around the house compound.

Almost all farmers surveyed reported insufficient amount of manure available for their personal use and those who do have it lack the farms equipment to either transport it to the field or incorporated it into the soil. It was encouraging to find that most farmers knew the value of manuring and were trying hard to acquire enough of it. In an interesting example in Cinzana (Mali), in exchange for free feed a cattle owner did agree to confine his herd in a designated area of a host farmer's field where manure and urine were deposited (Fig. 6 and Fig. 7).



Fig.6. Cattle must stay on the farm (Cinzana, Mali)

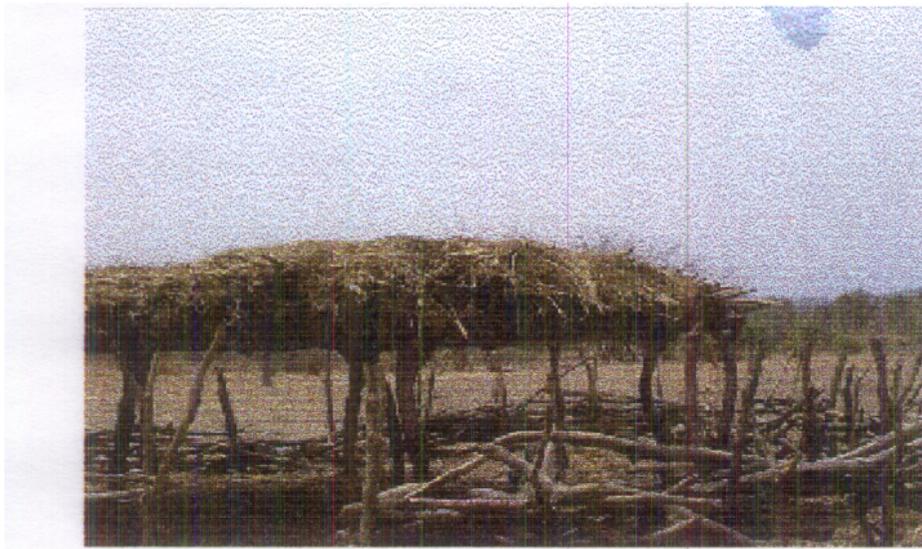


Fig.7. Aerial composting (Dougouba, Mali)

Composting (Fig.7,8,9) on the other hand, can be a very effective way to manage household waste through biological decomposition. Studies conducted in Africa have shown that favorable results can be obtained with compost (Scaife, 1971, Swift et al., 1994). Again, except for Cinzana, composting was not a widespread practice in the surveyed locations



Fig.8. Surface composting (Dougouba, Mali)



Fig.9. Underground composting (Cinzana, Mali)

Other researchers have reported that the lack of widespread practice of composting was due to lack of water and limited availability of plant and crop residues (Poulain, 1980). Ways to minimize constraints to manuring and composting must be further researched including how to improve its quality (nutrient content etc.) in order to be able to meet plant nutrient requirements. Managing manure for its P content can be also important for the region.

3. InterCRSP/West strategies to improve food production

Manure extender

Experience gained with the exploratory survey has stimulated InterCRSP/West collaborators to propose new ideas on how to address some the problems mentioned above. For example, experiments design to look at the synergistic effects of using a mixture of chemical fertilizer with manure are being conducted at Fansirakoro and N'Tetoukoro, Mali. This approach is important for several reasons. 1) We know farmers prefer chemical fertilizer over manure but they always have little to use. Therefore, an idea to mix the two in small quantities "manure extender" may be an attractive alternative, 2) Chances are that the inorganic fertilizer will be much more effective with the manure than separate (better water holding conditions in the manure etc., 3) Buffered changes in temperatures should improve root growth, 4) Improved environment for biological activity in the manure-inorganic fertilizer combination, 5) The manure may be providing other nutrients such as micronutrients that are not present in the inorganic fertilizer, but are needed in small amounts. For example the requirement of zinc would be very little and there may be enough in manure to provide for some excellent growth as long as the N, P, and K are supplied by the inorganic

fertilizer. In **fact**, **recent findings** support the synergistic **effect** of the mixture of manure and common fertilizers. Most importantly, this approach **does** not pit the manure against the inorganic fertilizer as competitors. **It likely should** stimulate the improved management of manure for use as an amendment for better **nutrient** management. **Finally**, it is a low **input** operation, the **only** requirement is access to a little inorganic fertilizer and the added **benefit** of saving labor **from** heavy **manuring** (R Yost, personal communication).

Determining the value of manure (Nutrient balances)

Currently, there are no **guidelines** for **determining** if manure applied is adequate for **crop** requirements. However, **the amount** of manure to be applied on a given field is dependent on the **nutrient status** of the field, the **nutrient** needs of the **crop** to be **grown**, the **nutrient** content of the manure. Therefore, the need for simple spreadsheet software to calculate **nutrient** balances on yearly **basis** is imperative. This approach **will** help achieve improved **nutrient recommendations** to **supply crop** nutrients at a rate that satisfies their needs and also **maintain** a balance in the **soil**. **Definitely**, without **such** an approach the process of **nutrient** depletion **will** continue and **even** become more severe every year.

Incentives for increasing production (Farm equipment, Markets, Prices of farms products and infrastructures)

The **unavailability** of **farm** equipment appeared to be a serious **concern** for the farmers surveyed. Farm work is physically demanding and because **most** farmers are old, working **manually** long hours **during** the cropping season without **any** equipment **can** reduce overall labor **productivity**. So., we believe access to a minimum **level** of **modern equipment** (cart to carry manure etc.) **may** boost **productivity**. **Analyzing experience** in northeast Uganda in terms of its implications for future development, both in Uganda and elsewhere in **Africa**, Carr (1992) pointed **out** two striking **facts**. The **first** was the rapid positive impact on the **productivity** of **small** farmers of a stable political situation **combined** with good infrastructure which tends to encourage **efficient** and **competitive** pricing. The second **is** the underestimation by **government** over **many** years of the farmers quick response to real **price incentives**. As a **result** of its apparent **lack** of understanding of the **underlying** forces which **motivate** farmers, successive **governments** have been providing initiatives that reduced both the quality of marketing and the **level** of economic **incentives** to **farmers**. This author went to add that this **remains** a common feature of governments in Sub-Saharan **Africa** today. Political exhortation or extension pressure is applied to farmers to produce **one crop** while pricing **signals** encourage them to produce another (**Cocoa** and **coffee** in Cote D'Ivoire, **Cotton** in Mali, **Peanut** in Senegal etc.). Alternatively, **campaigns** are mounted to encourage the use of purchased inputs while pricing **policies** are reducing the **benefit** to **cost** ratio of the proposed innovation.

We deeply concur with the author that this **may** be the most critical issue for the improvement of **African farming systems**, but **yet** it seems to receive remarkably little attention **from** **policy** makers and others. It is therefore apparent that research and **policy** action **should** be **directed** to both at **not only** raising the level of food supply but also to **increase** the average standard of living of farm households.

4. Conclusion

The problem of **nutrient mining** appears to be largely a **result** of both inappropriate soil **nutrient** management and fertilizer **cost policies**. **Evaluating current** technologies used in the region and adapted to existing farming practice appears to be the best option there is to **increase food output**. This will **require** both **fundamental** research and a greatly increased level of field **experiments** if the problems of **increasing** production, particularly in the **drier areas**, are to be solved. **Any measurable** result **invariably** will **depend** on the level of **understanding** of the real problems of the **small** farmer face and the **applicability** of these solution to these problems.

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**THEME 1: FARM PROGRAMMING AND COUNTRY
POLICY**

Farmer to farmer visit

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Abstract

Several activities, which deal with erosion, **salinity and loss of soil organic matter**, have been implemented in Cape Verde; however, there has been a **lack** of communication **among** farmers concerning the **benefits** or constraints of **such** activities. **In** order to **promote communication and** transfer of **experiences** between **farmers**, INIDA's researchers organized a **farmer-to-farmer visit** in the Ribeira Seca watershed. To conduct this **visit** a group **composed** of twenty farmers, two researchers and a **technician** spent a day in **different areas** of the watershed where **farmers explained** their **activities** related to soil **salinity, loss of soil organic matter and/or soil erosion**. Although **many** of these activities were **performed** in the **past projects** there was still **much** learn **from** those present. The visit was considered a **success** and farmers **suggested** that this type of **activity** is worth **repeating**. The impact of this visit **will** be monitored as part of the **InterCRSP** activities for 1999.

1. Introduction

In Cape Verde, soil **characteristics, topographic** conditions and **climate** constraints have produced a unique **agricultural system**. The two major systems of production are **rainfed agriculture** practiced mostly on the **hillsides** of the valleys (ribeiras), and irrigated agriculture **in the** valley bottoms and near the occasional water source. The prevailing rainfed agriculture **activity** on **scarce** arable land and population pressure have led farmers to **cultivate** on steep slopes. The **annual maize/beans** intercropping in these **areas** has accelerated erosion and soil degradation (i.e. loss of organic **matter**). Irrigated **crop** production **is** practiced whenever and wherever water **is** available. Water supply is the major **constraint** to production and there has been an **increase** in **crop** loss due to gradual decrease in water quality. **Since** Cape Verde has a short rainy season to replenish the **aquifers** farmers are **forced** to overpump their **wells**. The successive water withdrawal causes **salt** water intrusion **consequently** increasing soil salinity **over** time.

Several activities which deal with erosion, **salinity** and loss of soil organic **matter** have been implemented in Cape Verde; however, there has **been** a **lack** of communication among farmers concerning the **benefits** or constraints of **such** activities. With this **farmer-to-farmer** visit, INIDA's researchers intended to **promote** transfer of information and technology between farmers related to soil **salinity, loss of soil organic matter** and soil erosion.

2. Methodology

Visit preparation

In order to conduct the **farmer-to-farmer** visit we began by contacting several farmers of Ribeira Seca watershed **with experience** in **one** or **all** the **areas** related to our objectives. We **selected about** twenty farmers, **with something to teach or learn**, and explained to them the objectives of the visit. **Knowing** the **number** of people that would be involved in this **activity** we rented two vans to accommodate the **visitors** and ordered lunch as we intended to stay all day in the **field**.

The visit

The visit was done on July 27th. We left INIDA, S. Jorge at 8 AM with the farmers, drivers and INIDA's group composed of two researchers and one technician. The visit was done in different areas of Ribeira Seca watershed such as Lém Jorge, Macati, S. Cristóvão, Caiumbra, Mato Afonso, Mendes Faleiro Cabral, Godim and S. Jorge, where both rainfed and irrigated agriculture are practiced.

At the end of the visit and prior to returning home, we had lunch at a farmer's field while the visitors gave their impressions about this experience.

3. Discussion

a, Soil salinity

1. Farmers activities

Salinity was seen in most fields we visited, especially in those where flood irrigation is common. In order to overcome this constraint several farmers suggested that this irrigation method be replaced by drip irrigation. Others have been planting tomatoes closer to the wells followed by bananas and sugar cane since the former requires frequent irrigation and the closer to the well the less pumping is needed.

2. Researchers' perspective

Salinity of both soil and water cannot be solved overnight. Although farmers activities are satisfactory, there are other actions that need to be considered. For example:

- a. Crop rotation systems using salt resistant crops.
- b. Avoid removing sand from the coastal areas since it is causing salt water intrusion and decreasing water quality in the aquifers.
- c. Use of organic materials to improve soil structure and, consequently improve infiltration and drainage during the rainy season.

b. loss of soil organic matter

1. Farmers activities

Loss of soil organic matter is a constraint throughout the Ribeira Seca watershed. This problem has been difficult to surpass since, as explained by farmers, at the time of harvest they have to leave the soil bare in order to have some feed for the animals. Some of them, however have been using, when possible, animal manure and/or banana leaves in the soil to replenish its organic matter content.

2. Researchers' perspective

Generally the soils of Santiago island are low in organic matter (<1 to 2%) and the quantities of manure and/or organic materials necessary for major change in soil organic matter status are large. However, we would suggest, in addition to farmers activities, the use of compost made of household trash and other organic material to improve soil organic matter content.

c. **Soil erosion**

1. Farmers activities

In Ribeira Seca watershed **corn/beans** intercropping is the prevailing rainfed **activity**, but when practiced on steep slopes it results in aggravated **soil** loss and erosion. **Given** this problem, **many projects** have launched programs designed to reduce erosion **and promote soil** conservation. Of these programs we **emphasize** those that have been adopted by farmers of Ribeira Seca which they **demonstrated during** the visit:

- ⚡ Construction of water and soil retention structure **such** as dams, **bunds**, retaining **walls** and underground **reservoirs done** by public work fronts and the government.
- ⚡ Construction of contour vegetable barriers and contour rock wall **terraces** to decrease runoff.
- ⚡ Conversion of large **areas** of rainfed **corn/beans** intercropping to pigeonpea **since** as a **perennial**, it protects better against erosion.
- ⚡ Use of **crop** residue as **mulch** to increase **infiltration** and reduce raindrop impact.
- ⚡ Use of a **different** technique of **cultivating peanut** on the slopes, for example, by **cutting** ridges **along** the slope to act as water **channels** and decrease **hill** erosion on peanut fields.

2. Researchers' perspective.

Soil erosion **control** measures used in Ribeira Seca watershed have **significant** impact in **reducing runoff**; however, we believe that **many** farmers in that **area** are not aware of its **benefits**.

4. **Conclusion/Recommendation**

In order to **promote** communication and transfer of **experiences** between **farmers**, inserted in the **interCRSP activities**, **INIDA's** researchers **organized** a **farmer-to-farmer** visit in the Ribeira Seca watershed. **According** to the **farmers** who **participated** in this event, this **activity** was **successful** and **very** beneficial **since** they had the opportunity to **meet** other colleagues, learn and teach **some** techniques which **will help** them reduce **soil** salinity, **soil erosion** and loss of soil organic **matter**. They **suggested** that this **activity** should be **done** as **often** as possible involving farmers **from** other **areas** of Santiago island **since** they are sure there **is** a lot to learn. The consensus was that the farmer-to-farmer visit was a great **experience** and worth repeating.

Adoption and Farm Level Impact of Improved Fertility Management Technologies in the Sudano Sahelian Zone of The Gambia

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Abstract

Low inherent soil fertility and decreasing levels of chemical fertilizer use have partly explained the significant decline in crop yields in Gambian uplands. The problem has been aggravated by rapid expansions in cropped area and a reduction in the traditional fallow periods. Researchers are attempting to address this problem by evaluating alternative soil fertility management strategies in eastern and western Gambia. Initial results show increases in cereal yields resulting from the use of inorganic fertilizer in combination with chemical fertilizers.

Research efforts have so far focused on agronomic parameters, with little attention to important socio-economic factors that determine potential adoption and the subsequent impacts of these technologies. The introduction and adoption of new or improved fertility management technologies have important socio-economic and farm resource allocation implications, and an understanding of these factors would assist in the generation of technologies that are consistent with farmers' production objectives and adequately reflect the conditions and constraints facing farmers for whom these technologies are being developed. Also, use levels for external inputs like chemical fertilizer are determined largely by relative price levels. The significant decline in chemical fertilizer use in the country over the last decade has been attributed to sharp price increases resulting from the removal of farm subsidies.

The general objective of this study is to determine the adoption and farm level impacts of different soil fertility management technologies under alternative pricing policies. Whole farm models are developed to assess the adoption and farm level impacts of combinations of organic and inorganic fertilizer. The results show positive response to chemical fertilizer price changes. Area under millet increases dramatically, at the expense of groundnuts and maize, with a 25% decrease in chemical fertilizer prices. Also, levels of urea and compound fertilizer use and farm level profits increase with the decline in chemical fertilizer prices. The results show a slight decrease in organic fertilizer use under the lower input price scenario.

L Problem Statement

With rapid population growths and limited access to production resources like land and investment capital, Sahelians are under increasing pressure to address the important factors that have constrained agricultural productivity in the region. In some Sahelian countries, attempts have been made to address the problem of declining productivity through intensification of land use. Also, the introduction of draft animal traction technology in the Sahel over the last twenty years has resulted in vast expansions of area under crop cultivation and a near elimination of the traditional bush fallow system that was the principal means of regenerating soil fertility.

Low crop yields and persistent declines in the production capacity of Gambian upland soils are generally attributed to low inherent soil fertility and low levels of organic and inorganic fertilization to replace removed nutrients from the soil. Significant reductions in inorganic fertilizer use following the removal of farm subsidies during structural adjustments have resulted in rapid soil degradation in Gambian

uplands and a **failure** to replenish soil nutrients. In addition, access to organic fertilizer is **limited** for the **majority** of farm households. Rapid expansions in **area under crop cultivation** and a near **elimination** of the traditional fallow system have compounded **these** problems. It is not surprising, therefore, that a number of farmer constraint studies have identified declining **soil** fertility as a primary constraint to increasing **productivity** in the **farm** sector (Mills et al.; 1987; Boughton et al., Torrence, 1989; 1987; **Kebbe** et al., 1996).

Research efforts to address the problems of declining soil fertility in Gambia uplands have **intensified over** the last few years. The Cropping Systems and **Resource** Management Promam of the **country's** National Agricultural Research **Institute** continues to **evaluate** alternative fertility management options in a **number of on-farm** and station **trials**. These research efforts have focussed on establishing **crop** yield responses to alternative fertility management technologies. In eastern Gambia, **different combinations** of **crop** rotation and organic and **inorganic** fertilizer levels are **being examined** in trials initiated last year. Initial results indicate that application of **inorganic** fertilizer in combination with organic fertilizer **significantly** increased yields for millet, **maize** and groundnuts. In the western **half** of the country, a **long-term** trial **aimed** at assessing the long-term **effects** of soil amendments and the interaction of manure and various levels of inorganic fertilizer was initiated last year. Initial results indicate that organic manure in combination with chemical fertilizer gave higher **mean** yields than inorganic fertilizer alone. Similar studies in Mali and Senegal have also reported positive yield responses to inorganic fertilizer used in combination with organic fertilizer.

As already pointed **out**, **agricultural** research efforts on soil fertility management have so far focussed on **agronomic** parameters, with little attention to important socio-economic factors that would **significantly** determine potential adoption and! the subsequent impacts of these technologies. The introduction and adoption of **new** or improved fertility management technologies have important socio-economic and. **farm resource** allocation implications, and an understanding of these **factors** would **assist** in the generation of technologies that are consistent with farmers' production objectives and adequately **reflect** conditions and **constraints facing** farmers for **whom** these technologies are being developed. This is critical for the sustainability of introduced **farm** technologies and potential payoffs to soil fertility maintenance research in The Gambia. As efforts to generate sustainable soil fertility amendments continue, the following questions are important.

- **Given** farm **resource** endowment and potential performance of the technologies being tested, what is the potential of adoption (i.e., **Who** will adopt, what will they adopt, how **much** will they adopt)?
- How **will** adoption of technologies affect farm level **resource** allocation and **crop** / livestock mix in both the short and long run?
- What **will** be the **farm/household** level impact (farm output and income) of adoption.
- How sustainable are these technologies?
- What are the **effects** of alternative farm **policies** on the sustainability of potential technologies?

Addressing these **questions** will be critical to the long-run viability of **potential** interventions to address the problems of **soil** degradation in the country. An important **consideration** is that agriculture in the country be considered **from** a holistic approach. At the level of the small farmer, **soil** fertility maintenance is viewed from a whole farm

perspective, with farmers taking advantage of residual **nutrients** from previous applications through **crop** rotations, tethering of livestock and short-term fallow. The adoption of improved soil fertility maintenance strategies would **definitely** have **resource** allocation implications at the household level, and it is important to **understand** these. Also, farm households **from different** resource categories **may** adopt **different** strategies, **and** it is, therefore, important to have an **understanding** of the **different** farm resource categories in the intervention **areas**.

2. Objectives

The general goal is to determine the adoption and **farm** level impacts of **potential** soil fertility management technologies. The technologies evaluated are; use of **organic** fertilizer at 2.5 tons per hectare, use of inorganic fertilizer at the recommended rates, use of half the recommended rate of inorganic fertilizer in combination with organic fertilizer, use of the recommended fertilizer rate in combination with organic fertilizer, and a control of no organic or inorganic fertilizer. In addition, **different** fertilizer prices are used to **evaluate** the **effect** of alternative **input** pricing **policies** on the adoption and farm level impact of improved fertility management technologies. **The specific** objectives of the review are to:

- 1) Determine the farm level adoption of **different** combinations of inorganic and organic fertilizers in upland fields,
- 2) Determine the impact of new fertilizer management technologies on cropping patterns
- 3) **Identify** the **farm** level profit **effects** of improved fertility management technologies; and
- 4) Determine the **effects** of inorganic fertilizer **price** changes on the adoption and farm level profits impact of improved fertilizer technologies.

3. Methodology

Study Area: The Sudano Sahelian Zone

Agroecological Characteristics

One of three major agroecological zones in the **country**, the **Sudano** sahelian zone covers all of Gambia **except** the Western Division and extreme north of the Central River Division. The zone is characterised by **savanna** woodland vegetation with an average **annual rainfall** of 600 to 800 mm. Like other regions in the **country**, rainfall in the **sudano** sahelian zone is **very erratic**, and the **rainfall** window has decreased consistently **over** the last **decade**. The period of plant growth ranges from 90 to 100 days, **beginning** in July and **ending** in **September/October**.

Production Systems

The principal upland **crops** in this zone are **groundnuts**, millet, and maize. **Sorghum**, **sesame**, **cotton** and cowpea are also produced but to a limited extent. Agriculture in the **sudano** sahelian zone is characterised by both traditional rainfed and semi-intensive production systems. The traditional **rainfed system**, referred to the 'low input extensive upland system', is characterised by extensive cultivation made possible by a relatively low **population** density. **Low** levels of **crop management** in this system are apparent in extremely low plant populations, use of traditional **crop** varieties and limited use of external yield augmenting inputs like inorganic fertilizer. Production increase is largely accounted for by expansion of **area** under cultivation. **The semi-**

intensive **system** on the other hand is characterised by the use of improved production techniques and the use of external inputs like inorganic fertilizer. In addition, a higher **crop-livestock** interaction under this system facilitates greater access to organic fertilizer.

Primary Constraints

Declining soil fertility has been **identified** as the principal **constraint** to agriculture in the sudano sahelian zone. The problem is **attributed** to low levels of **inorganic fertilizer** use, decreasing **fallow** and **continuous** cropping. In **inland** villages away **from** the river, reduced access to organic fertilizer due to the **out-migration** of livestock **during** the long dry season has compounded the problem. Soil erosion, **lack** of access to **farm credit** and pest control chemicals, and inadequate farm labor supply are other important constraints to the farm sector in this zone.

Land Use and Farm Mechanisation

In the Sudano Sahelian zone, land use is categorised by both plot location and structure of ownership. **Inner** fields are located close to village settlements and **receive** most of organic **fertilizer** used for **crop** production. These fields are **usually** tethered **during** the dry season, and then put to maize the **following** rainy season. **Outer** fields on the other hand receive **very** little organic fertilizer and are used predominantly for the production of cash **crops** like groundnuts. In terms of **ownership**, fields can be either cultivated individually or communally. **Individual** fields are **generally** put to **groundnuts**, which is the principal cash **crop**. Household **staples** are **cultivated** on communal fields.

The majority of farm households in the Sudano sahelian zone either **own** or **have** access to **draft** animal traction. **Oxen**, donkeys and **horses** are the **predominant** sources of draft power in this zone. Crop production activities for which animal **traction** power is used **include** **seeding**, **weeding** and **harvesting**. Like in **most** parts of the country, deep **plowing** is uncommon in the sudano sahelian zone. Dry seeding just prior to the **first rains** or direct seed immediately **after** is the most common practice.

Data Requirements and Sources

Data requirements **include** **human** and animal traction labor requirements and supply, **input** and output **prices**, **crop yields**, farm **resource** endowments and seasonal **weather** variation'. **Human** labor requirements are based on labor budgets for the key **crops**, and supply is based on the structure of the typical farm household. Crop yield data are derived **from** adjusted results of trials conducted at the research stations and on farmers' fields. **Resource** **endowment** covers land, liquidity and other **farm** inputs.

The Theoretical and Empirical Models

The adoption of soil **fertility** maintenance **strategies** can be **seen** as a problem of portfolio allocation **since** adoption requires the allocation of farm **resources** given production objectives and **resource** constraints. An **ex-ante** evaluation of the **different** technologies (**from** a whole farm perspective) is **done using** mathematical programming to **simulate** farm level adoption and profit **effects** of soil fertility management technologies. This paper adapts the model developed by **Coulibaly** (1995) and uses the Direct Expected Utility Maximization (DEMP) **program**² which is generally formulated as:

1 Data used for the models represent best estimates and are subject to modification following verification. The model results presented later are therefore illustrative.

2 For a detailed **presentation** of the theoretical model, **see** Coulibaly, 1995

$$\text{Max } E[U(W_s)] = \sum \theta_s \cdot U(W)$$

where a **negative exponential utility function** is given as

$$U(W) = -e^{-rW}$$

Here

W_s = **vector of net revenues from crop** production activities

s = states of nature

$E[.]$ = expectation operator

$r > 0$ = coefficient of **absolute risk aversion**

Crop production activities are undertaken **subject** to resource endowment constraints to **cover** availability of land, **human** labor, **draft** animal traction and liquidity. In addition, non-negativity constraints are imposed on all **decision** variables. For **each** resource category, the **constraint** is depicted as;

$$\sum A_{ij} X_{ij} \leq L_i$$

where A_{ij} = **input requirement for crop activity j** at period **I**

X_{ij} = hectares of **crop j** at period **I**

L_i = resource availability at period **I**

The objective **function** in the empirical model is to **maximize** the expected **utility** of net farm revenue subject to constraints on access to liquidity, land, **human** labor **and** animal traction **power**. The farmer is assumed to be risk averse and production activities **cover** three **crops** using **five** **fertility** management options per **crop**. The model thus **includes** a total of **fifteen** activities. Three states of nature and their probabilities of occurrence are used for **computing** expected **yields** and farm **profits**. **Output prices** also **vary** by state of nature. **Liquidity** and total land available for production are restricted to **reflect** access to these **resources** by small and medium farm households in the Sudano Sahelian zone. Production activities are broken into **five** periods and constraints on **human** labor and animal traction **availability** **reflect** total time **available** for **identified** activities and the active labor force and number of animals per farm household in **the** zone.

4. Discussion of Results

The **model**³ is constructed to **reflect** production practices **with different** fertility management technologies. Crop varieties and **cultural** practices **reflect current** farmer practices. The results represent optimal **crop choices** under **different** organic and **inorganic** fertilizer regimes. The control treatment **reflects cropping** with no **organic** or **inorganic fertilizer**. Other treatments are; use of organic fertilizer alone at 2.5 tons per hectare, use of chemical fertilizer alone at the recommended rates, use of organic plus inorganic **fertilizer** at half the recommended rate, and use of organic plus inorganic **fertilizer** at the recommended rate. The **crops** considered are groundnuts, millet and maize. Sorghum and **sesame** are not **included** in the models because they represent a **very small** proportion of the total cereal production. The base model represents production **choices** under **current** inorganic fertilizer price levels. The model is then re-estimated assuming a **reduction** in the **price** of inorganic fertilizer. **This scenario** depicts

³Coefficients are based on estimates and may not be accurate representations. All models will be re-estimated using more accurate coefficients.

a pricing policy where the output prices increase relative to **input** costs. Estimation results are discussed in this section.

Technology Choices and Total Farm Output

Optimal Soil **fertility** management technology **choices** and output under the two price **scenarios** are presented in Table 1. **At** higher inorganic fertilizer **costs**, the optimal **plan** is to use lower levels of inorganic fertilizer. The results **indicate cultivating** 3.984 hectares of maize using organic fertilizer **only**. Groundnut is **also** cultivated using a **combination** of inorganic and organic fertilizers at half the recommended rates. These results depict the trend in inorganic **fertilizer** use in Gambia **over** the last **decade**. With the **removal** of fertilizer subsidies, a sharp increase **in** the **cost** of inorganic fertilizer has **resulted** in significant **declines** in chemical **fertilizer** use. In the sudano sahelian zone, maize is cultivated in inner fields close to the village, and these fields receive most of the organic manure used for production. Groundnut on the other hand is cultivated primarily in **outer** fields and is a priority **crop** for inorganic fertilizer application **This could** be because groundnut is the principal cash **crop**, **hence** more likely to receive external inputs like chemical **fertilizer**. Millet is not included in the optimal plan given the higher price **scenario** although it is the staple cereal in the **sudano** sahelian zone. The results suggest that **at** higher **input** costs, it is not profitable to **invest** in external inputs for millet production.

The second **scenario** illustrates the **farm level effect** of **increasing** output price relative to **input** costs. Here we assume a policy of a decrease in the real **cost** of **inputs**. The results show a **significant** decline in maize and groundnut production at lower chemical fertilizer prices. **Resources** are **diverted from** maize and **groundnut** to millet production under this price **scenario**. Use of organic fertilizer alone continues to be the optimal technology **choice** for maize. For both groundnuts and millet, the optimal plan is to use half the recommended rate of chemical fertilizer in combination with organic fertilizer. The results suggest higher levels of cereal (millet) production. at affordable fertilizer price levels. This is **consistent** with arguments that for cereal production to be attractive to small-scale producers in the country, output prices **must** increase relative to chemical fertihzer costs. This has important policy implications and will be a **focus** of further analysis following re-estimation of coefficients and data modification.

Table 1: Optimal Crop Choices and Output Levels under Different Price Scenarios

Technology	*Scenario A		*Scenario B	
	Crop Area (ha)	Output (kg)	Crop Area	output
** Millet (C4)	0	0	3.027	4607.8
Maize (C7)	3.984	3854.376	1.407	1361.02
Groundnuts (C14)	2.016	3268.379	1.5664	2539.088

* Scenario A. existing fertilizers prices, Scenario B: 25 % reduction in fertilizers prices

** C4 = Millet with half the recommended rate of chemical fertilizer plus manure

C7 = Maize with manure only

C14 = Groundnuts with half the recommended rate of chemical fertilizer plus manure

Input Levels and Expected Farm Profits

Model results for input use levels and expected farm profits under the two price scenarios are presented in Table 2. The results show that inorganic fertilizer use among farm households continue to decline with higher chemical fertilizer price levels, resulting in decreasing expected farm profits. At higher inorganic fertilizer costs, the optimal plan supports using chemical fertilizer on groundnuts only, the primary cash crop. Under this scenario, compound (NPK) fertilizer is used for groundnut production, with no investment in urea. Organic manure is used for both maize and groundnuts production. The results explain the sharp decline in chemical fertilizer in The Gambia following the removal of input subsidies and sharp increases in the price of inorganic fertilizer.

Table 2. Input Levels and Expected Farm Profits under Different Input Prices

Input Level/Farm Profit	* Scenario A	Scenario B
Urea (kilograms)	0	151.349
Compound (kilograms)	100.807	305.338
Organic Manure (tons)	12.48	9.26
Expected Farm Profit (Dalasis)	D 15113.678	D 15557.254

* Scenario A existing fertilizers prices; Scenario B 25 % less costly fertilizer.

Constraints to the Adoption of Fertility Amendment Technologies

Land, labor, animal traction and liquidity constraints are specified in both models. Binding constraints and their shadow prices are shown in Table 3. The results show liquidity and land to be binding under both price scenarios. The lower shadow price for liquidity under the higher price scenario provides further evidence of decline in chemical fertilizer use with input price increases. The decline in chemical fertilizer

use implies lower liquidity requirements for inorganic fertilizer purchases. **With reductions** in the relative **price** of chemical fertilizers however, increases in the levels of urea and compound fertilizer result in a higher **liquidity** requirement. The **shadow** prices for land are extremely high under both **scenarios**, suggesting that **the** specification of the land constraint in both models **may** not **reflect** farmer **circumstances**. This issue will be **reviewed** **when** the models are re-estimated **using** more accurate coefficients.

Table 3. **Farm Constraints under Different Price Scenarios**

Constraint	Shadow Price	
	* Scenario A	Scenario B
Liquidity	101.921	111.993
Land	9341.651	8229.947

* Scenario A – existing fertilizer prices; Scenario B – 25 % less costly fertilizer

4. Recommendations for Future Research

General Recommendations

The **successful** introduction of new technology requires an **understanding** of the important factors underlying potential adoption. An **understanding** of farmer behavior **is** critical to the adoption of new technology. It is important to understand the socioeconomic characteristics **and** behavior of **farmers** for whom technologies are being developed. **Among** these **include** the **resource** base of farm households and the impact of farmer behavior on technology adoption. **Technology** adoption is **very often** a problem of portfolio allocation, addressing questions of **what** will be **adopted**, **what** will be the mix of new and old technologies, what proportions of farm **resources** will be allocated to the **different** technologies, etc. There are **differences** in resource endowments at the **farm** household level, and it **may** be **useful** to **distinguish** between high, **medium** and low **resource** categories so that **recommendations** can be made for a broader range of producers based on levels of **resource** endowment. **Very often**, whole **farm** models are developed for the ‘average or **representative** farm’, and it **may** be **difficult** to use results **from** **such** models to make **recommendations** if levels of **resource** endowment are different.

Given farm **resource** constraints, the levels of **resource** endowment will determine what technologies are feasible and what the mix of **different** technologies will be. **Different** soil fertility management strategies **may** require **different** levels of **investment** in **inorganic** fertilizers, other farm inputs, labor and implements. **In** addition, there are implications in **terms** of **ownership** and **control** of livestock and **access** to organic fertilizer. The Mali models for example use a representative farm with a land **endowment** of 19 hectares. The result is that land **does** not come **out** as a **binding** constraint. However the initial argument is that high **population** pressure, **together** with the introduction of animal traction and near **elimination** of traditional **fallow** have increased pressure on **farmlands**, accelerating soil degradation. **One** would therefore

expect some form of land constraint. Land could be an important constraint for households with low and medium resource endowments, and **this may** result in **different** adoption behavior and **different farm** level impacts. Whether or not land is an important constraint could have **significant** implications for soil fertility management, and this **needs** to come **out** in **any** analysis of **fertility** management technologies. Similar arguments hold for labor or other inputs. Dalton (1996) for example **differentiated** between highly capitalized and **less** capitalized **farms** in **southern** Mali because 'less capitalized **farms** have only half the livestock **units per** hectare of **highly capitalized farms**. As **such**, their response to opportunities to **intensify crop** production with organic **fertilizers**, derived **from** animal **manure**, is dramatically **different** than highly capitalized **farms**.' It may therefore be **useful** to develop **farm** models reflecting at least **three** resource endowment **categories**, medium, low, and high. **Sensitivity analysis** might do it, but **experience** with 'adjustments of cropping **systems** to producer **price** changes in eastern Gambia' is that better results are obtained by looking at **different** resource **endowment** groups. This **will** involve going **back** to the survey data and looking at household resource **levels** to **see** how they **vary**.

The response of **farmers and** farm households to **different** technologies **will** be important in determining the relative merits of **different** fertility management interventions. In addition, there is a need to **be** able to determine the **potential** household or farm level impacts of introduced versus existing technologies. In this regard, **it** is important to develop an **understanding** of who the potential adopters are, what the **constraints** to adoption are, **what potential** technologies will be adopted, how **much will be** adopted (*i.e.*, mix between new **and** old), and what the implications are in **terms** of resource allocation and meeting **farm** production objectives. **It** is important to be able to determine the value of mitigating **constraints** to the adoption of **specific** farm technologies and **evaluate** the **effects** of alternative **farm policies** on adoption and **farm income**. The **Mali** model evaluates **technology** impacts under devaluation, and the results **suggest** that **policies** that affect the relative **prices** of inputs **and** farm output **will** determine adoption and **farm** level impact. **Initial** model results for **Gambia** support these results and need to be **further analysed**.

Also, the models estimated in this paper consider only **one** level of risk aversion, **and** incorporation of **different levels** of risk aversion will give an indication of how farmers will **respond** to technologies under **different** levels of risk aversion. Soil fertility management **has** important long-term **considerations** that are central to the **sustainability** of interventions. Crop rotations (like cereal-legume rotations) **and** short term **falloffs** are used to **make** effective use of residual **nutrients from inorganic/organic** fertilizer application. The **general objective** of the **soil fertility** maintenance research project in **Gambia** is to **build up** soil organic **matter** and **nutrient** content **over time** to support **sustainable** production. **It** is therefore important that **socio-economic** analyses of these trials take **account** of the long term sustainability of the interventions. **Following** the development of farm models to **evaluate** potential adoption **and** farm level impact of fertility management technologies, **sustainability** can be evaluated using **dynamic/multi-period** programming.

Specific Recommendations

For **Gambia** we **intend** to **build** on the **experiences** of this paper and work in **Mali** to develop **farm production** models for three principal zones; Sahelian, Sudano Sahelian **and** Sudano Guinean. These zones are the **focus** of **current** national agricultural research efforts. Unlike Mali and **Senegal**, more work is needed in **Gambia** on **putting** together data for programming work. Options **include** supporting modest

farm surveys in intervention **areas** or adapting data fi-om similar zones in other countries of the region where **this** Us applicable. Although Gambia is not in the CFA zone, its physical location and volume of trade **with** Senegal warrants a look at the impact of some CFA zone **policies like** devaluation. This would allow good comparative analysis.

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Improving and Sustaining Food and Raw Material Production in West Africa: A Participative Rapid Rural Appraisal in Fansirakoro

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1. Introduction

The context of the Participative Rapid Rural Appraisal (PRRA)

Farmers like researchers, extension workers and firms are involved in **generating**, **transferring** and utilizing technologies. In **this** respect the farmers' common knowledge should be part and parcel of the dominant paradigm of the development process. We **can** assume that **farmers** have a crucial contribution to make, or rather, are already **making** a crucial contribution by their **continuous** effort to adapt their farming to the **changing environment**. Farmers' effort should be integrated in our effort of official system of technology development process. **Knowledge** development and utilisation **is** the key **ingredients** for **continuity** and growth in a society. Farmers and their knowledge are potential components of **the institutional knowledge system** which **can** or **cannot** be utilised to **advantage** for rural development. In this process **farmer can** be considered as a **knowledge** manager.

This Participative Rapid Rural Appraisal (**PRRA**) was **done** as an attempt of **capturing farmer's** research effort as a basis for **InterCRSP** research **and/or** technology development process. This paper **summarizes** the methodology and preliminary **results** of a participative rapid rural appraisal conducted in **the** village of Fansirakoro in **Southern** Mali Fansirakoro **is** located in the Zone of the **Office** de la Vallée du Niger (**OHVN**). The **thirty-eight** rural **agricultural** production units (**RPU**) of Fansirakoro were surveyed and in-depth, **open-ended** interviews were **conducted** with the heads of **PU**s.

2. Objective

The main objective of this **PRRA** was to **provide baseline information** on the **farming** systems **found** in the OI-IV zone of Kati in order to **establish** research priorities for the **InterCRSP** NRM project.

3. Sites presentation

The OHVN Zone

The Office de Developpement de la Haute Vallée du Niger (OHVN) is a government agricultural development parastatal **institute** created in **July** 1983. Its zone is divided into six (6) administrative **sectors**: **Kangaba**, Ouelessebougou, Bancoumana, Koulikoro, Kati and Banamba. These **sectors** were subdivided into **thirty Zones d'Expansion Rurale (ZERs)** and the **ZERs** were further subdivided into **one** hundred and sixty **Secteurs de Base (SB)**. The OHVN provides technical and extension services to approximately **nine** hundred and thirty **nine** villages and settlements in the **area**.

The population of the OHV zone (533,687 persons in the last census in 1998

comprising 265,029 males and 268,658 females) is predominantly rural, deriving the majority of revenues from agricultural activities. The population density is 16 inhabitants per Kilometer Square. The annual population growth rate varies from 3 to 3.5%). The main ethnic groups found in the area are the Malinké, the Bambara, the Sarakhollé, the Peulh and the Bozo.

The OHVN zone encompasses an area of 34,500 km² which represents 2.5% of the Malian territory and 11% of the cultivated rainfed area. It covers the area immediately surrounding the capital city, Bamako, and hence has access to the largest market in Mali. The climate varies from Sahelian (600 mm rainfall) in the northern sectors of Banamba and North Koulikoro, to Sudano-Sahelian (1,200 mm rainfall) in the south of Ouelessebouyou, Bancoumana and Kangaba. From 1981 to 1985 rainfall was low, but in 1986 the drought appeared to diminish and the pattern approached the 50 year average. The mean temperature varies seasonally from 26 to 36°C.

Arable lands in the OHVN zone represent 60% (20 820 km²) of the total land area and only 7% (145,700 ha) of the total arable land are cultivated. The plains classified as Typic Ustropepts are soils of fine silt, clay materials, or sand, laying over lateritic hardpans. The topography of the region is dominated by the Mandingue mountains in the sectors of Kati, Bancoumana, Kangaba and Koulikoro, and the Niger river, which crosses the region from Southwest to Northeast. Lands of variable topography lay between the Niger and the mountain chains. Mountains and cliff areas have predominantly rock outcroppings and wash areas.

The broad alluvial plains of the Niger are the agricultural heartland of the region. Rice, millet, sorghum, vegetables, and cash crops grow in this area. Rice is also grown in Eowlands around the villages. In the sectors of Kangaba, Bancoumana, Ouelessebouyou, Kati and South Koulikoro, millet and sorghum are grown in gravelly sandy soils (typic CuirustalFs), generally clay-silt or silt-clay mixtures. In the dominantly agropastoral sectors of Banamba and North Koulikoro, souna millet is the principal crop. Tree crops (mangoes, karité, etc..) are also important throughout the region.

The road system in the OHVN Zone comprises four main axes starting at Bamako in the directions of Kati, Banamba, Kangaba and Ouelessebouyou. In addition, the area is served by a network of secondary roads, many of which become unfit for motor vehicles during the rainy season. Health and education centers are located mainly in the larger urban centers and the main villages in some Sectors de Base. These centers are more developed in the Sectors of Kati and Kangaba than in Banamba, where there are rare.

The Sector of Kati, the site of the project corresponds to the administrative circle represents about 47% (16 100 km²) of the total area of the OHVN zone. It is divided into three natural regions, the Plateau mandingue (PM), the Plateau of Koutiala (52.38%) and the Haut Bani Niger which represent respectively 52.38%, 10.8 % and 37.45% of the area, respectively (PIRT, 1986).

The Plateau Mandingue comprises two agro-ecological zones (PM4, PM5) which represents respectively 19.4 % (3210 km²) and 32,98% (5310 km²) of the total area of the sector of Kati. PM 4 is located in the Southeast part of the Monts Madingue in the south Soudanian zone. Arable lands cover 44% of the Monts Madingues and are located in the valleys. Soils are quite deep and well drained. Non arable lands cover 53% of the area. These soils are shallow and very susceptible to erosion. Rocky soils compose 3% of the Monts Mandingue area.

The Wenia agro-ecological zone (PM5) is limited in the East by the Plateau of Koutiala (PK) and the Haut Bani Niger, in the West by the Gangaran, in the South by the Monts Mandingue and in the North by the Bélédougou. This zone is located in the South

Soudanian zone. Arable lands cover 74% of the **Wenia** zone and non-arable lands 22%. Fansirakoro belongs to this agro-ecological zone.

The second natural region, the Plateau de **Koutiala** is limited to the North by the **Niger** Delta, to the East by the Plateau of **Banfora** (Burkina Faso), to the west and South-West by the Haut Bani Niger (**HBN**). Rainfall varies from 650 mm to 1300 mm. The agro-ecological zone of the Moyen **Bani** Occidental (PK3) which concerns the sector of **Kati** is located to the West of the Moyen Bani and Oriental (**PK2**) runs through **Baguineda** up to the **Bani-Bagoé** river system. Arable lands covers 53% of the total area and are dominated by plains (41%)

The **third** natural region found in the sector of **Kati**, the Haut Bani Niger (**HBN1**, 19.87% around 3200 km², and **HBN2**, 17.58% around 2850 km²) is limited by the Plateau mandingue in the **Northwest**, the Plateau de **Koutiala** in the **Northeast** and the East, the Plateau du Foniokourou in the South and by the border of the **Country of Guinea** in the **West**. It is divided in four agro-ecological zones from which two zones are part of the sector of Kati

The Haut **Bani-Niger** occidental agro-ecological zone (**HBN1**) is located to the South of the Monts Mandingue and the **Malian-Guinea** border to the **West**, and the Moyen Baoule to the East. The climate is of the **South** Soudanian type. Arable lands represents 70% of the total area of the zone. The **HBN2** corresponds to the agro-ecological zone of **Djitoumou** which is located to the **South** of the district of Bamako. It covers the extreme North of **HBN1** and its climate is of the **South** Soudanian type. Arable lands represents 85% of the **Djitoumou** zone.

4. Methodology

The team before the survey conducted a **literature** review. It included documents from the **different technical** divisions of the OHVN, **annual** reports, follow-up reports, **specific** reports for **assessments** and monitoring. **Discussions with resource persons** (extension **staff at OHVN headquarters** and in the **Sectors of Kati**) were also conducted.

The survey was performed with the help of an **open-ended informal** topic guideline at two levels: village and production unit (PU). Its **informal** nature contributed to the **open** and flexible interviews that the multidisciplinary teams were able to **conduct** with the **farmers** at the time of survey implementation. The outline was developed by team members **using** a format from the farming systems and natural resource management team, and reviewed by OHVN personnel before going to the field. A sample topic guideline is presented in Appendix 2.

The methodological approach used for the survey comprised three steps by which the **choice** of ZER, SB, villages and PUS was made in a **logical sequence**. The first **step**, the **choice** of Fansirakoro was done during the **InterCRSP** preliminary survey in the Sector of Kati in **October** 1997. OHVN extension staff were part of the preliminary survey team. The shallow soils and degraded land due to low soil fertility and soil **erosion** characterized the situation of Fansirakoro compared to Torodo where shallow, **rocky** and very degraded soil was predominant

The second step consisted of an interview with the population of the *village* which involved mainly the village chief, several counselors, a few other dignitaries, and available heads of PUs. The size of the group during that interview was about 40 participants. The interview at that level was supported by one section of the open-ended topic guideline.

The **third step included** interviews with the **PU**s heads and were conducted using the **specific** section of the **open-ended** topic guideline. The **choice** of the **PU**s heads to be interviewed was based on their availability. The interviews were completed by a field **transect** of the village.

A multidisciplinary survey team conducted the PRRA. The team **included** six researchers **specialized** in the disciplines of **agricultural economics**, animal science, **ecology**, agronomy, soil science and **gender** issues. OHV extension agents and natural **resource** management program **officer** assisted in **conducting** the interviews **with farmers**. For the interview process, **beginning** with **PU**s, the team was **split** in groups of two members of **each**. The **survey** was conducted in **6 days**.

Once the survey was completed, **individual** reports were **prepared** following the **outline** of the topic **guideline**. The data were also handled by Paradox Software and analysis was completed using the SAS system. The farming **systems identified** were described, and hypotheses were formulated regarding the principal **constraints** of the farming **systems**. When possible, **recommendations** to alleviate or remove the **constraints** were proposed. A list of these **constraints** and **recommendations** is presented in the Results section of this report. The plan of research for the next years is based on the **identified constraints**, **modified** by additional information gathered by the team through other activities.

5. Results

The village of Fansirakoro shares the **same** terroir with **Fabougoula**, **Fansiratiani** and **Fansiradjèrobougou**. The terroir of **Fansirakoro** is **bordered** by the village of **Kobala** at 3 km to the **North-West**, by the village of **Djini djala** at 6 km to the **West**, the village of **Sidjè** at 4 km to the **South** and the village of **Yèkègougou** at 8 km to the **East**. The total **area** of the village **is about** 225 km² (22,500 ha). **Fansikoura** and **Fansirakoro** are the two main hamlets known **under** the **name** of **Fansirakoro**.

a. Population

The **population** in the village of **Fansirakoro** (**570 persons**) is **predominantly rural**, and most revenues are derived from **agricultural** activities. The average labour force is **10 persons** per **PU**. The **Bambara** is the **only ethnic group** existing in the village of **Fansirakoro**. The **Bambara** **occupy** the **OHV** zone, the central part of the zone of **Kati**, the **Ouelessebourgou** East and **Koulikoro**. The primary occupation of the population in the village **is agriculture**.

The village of **Fansirakoro** is organized in five extended families (**Sirimana**, **blacksmiths**, **Tièkourabala**, **Dossorola** and **Dionkèla**). The thirty eight production **units** of the village **belong** to these five families. The **blacksmith family** has 13 production **units**, the **sirimana family** 11, **Dossorola** and **Dionkèla families** 5 each and the family of the village **chief** (**Tièkourabal**) 4 production **units**. The average population per **PU** is **about** 16 persons comprising of 7 **females** and 9 **males**.

The population of the village is living in two main hamlets (**Fansikoro** and **Fansirakoura**). The history of the village **started** with three brothers who left the village of **Fabougoula** to settle in **Fansira**. The village was established more **than two centuries** ago. The founder of the village **Samassékoro Traoré** and his two brothers came from **Fabougou** looking for good **agricultural** lands. The village used to be a cereal **market** for **nomadic** population (**Maures**). The production of the village gave the population

some authority in the surrounding **area**. These conditions of authority (**Fama**) and good production (finsoro) gave the **name** of **Fansira** to the village.

The population of Fansirakoro' is **practising** Islam, **Christianism** and Traditional religions. **Fifteen** chie& have ruled the village since **its establishment**, which was before the arrival of colons The **actual chief is ruling the** village **since** 1983. Four counselors **assist** the head of the village and by the **council** of **elders**, which comprises the village chief and **representative** of every extended **family**. The village of **Fansira is organized** into clans or large **families** forming what is defined as a Production Unit (PU). **All families live in large farm family units** (Pus) **around** a patriarchal leader and work in communal **fields**. The Pus comprise on the average 2 to six households, with an active **farm** population of 16 **members**. **Individual household size varies from** 3 to 35 members.

Management decisions regarding allocation of land **crop choice**, use of agricultural **equipment**, and **distribution** of production are made by the **patriarch** of the PU. **Individuals responsible** for **specific fields** make decisions on the daily operations in those **fields**, and are **accountable** to the **head** of the PU.

A **typical farm includes** both communal and **individual fields**. **Women**, heads of households and **young active males**, **cultivate individual fields**. Women produce **peanuts**, **rice** and millet for the local markets in **these fields**. In **fact**, there are **wide** ranges of field types used by the **farm families**; there are village **garden** plots used to produce condiments, **near-village fields**, **bush fields**, **low-lying fields** and **flood recession** fields, if available. Management decisions on labor and other **inputs** to **each** of these type of fields **derive from** a **complex** weighing of **constraints**, **risks**, and expected **benefits**.

Several communal organisations (*N'tonchi*, *Guatchi*) are available in the village of Fansirakoro. They are **traditional in** the village and **mainly age** sets or peer groups. They are **mainly active in agricultural and cultural** activities in labor management at the village level. **Labor migration, although largely seasonal, is important enough** in the village. **Migrants are often males and females** between the age of 14 and 30. They travel **mostly** to Bamako and Kati.

The **Yèkèbougou-Fansirakoro road** is the main road **that** serves the village. A network of roads serves **other areas**, which **might** be inaccessible **during** the rainy season because of **waterways** and **mountains**. **There is a lack of formal education and** the rate of illiteracy is extremely high. The impact of **Government** effort of alphabetization is not high in Fansirakoro.

The **survey** shows a **widespread illiteracy** in the village, which poses a problem for **agricultural** and social development. The school and **market** are located in Yèkèbougou. The OHV is the **principal governmental agricultural development agency** operating solely in the viige of Fansirakoro. **Several rural development institutions** have operated in Fansirakoro.

The **Water development department** established an **equipped well** in 1987. A religious **NGO (Secours Catholique)** also established two large **wells** and a **milling** machine. **The same NGO helped** the village **establish a cereal bank**, a rural **maternity clinic**, a community pharmacy but **none** of these is **functionning** at present.

The village of Fansirakoro **has good relationships** with **neighbouring** villages (*Djinidjan*, *Fabougoula*) **including** mariages and source of agricultural labor. The village of Fansirakoro is **located** on the **lands** of the village of *Fabougoula*. The chief of the village of *Fabougoula* is the owner of the lands. However, there is no **problem** with regards to the land use **rights** even though land **rights** belong to *Fabougoula*. Soils in Fansirakoro comprise low-land soils (very low potential), very degraded, rocky soils (upland soils) which are dominant and plain soils.

Upland soils can be cultivated for 6 years. After that period striga appears and yields of crops may decline. Fallow can take 15 to 20 years before the fertility can be restored. The growth of trees (*Terminalia sp.*, *Combretum sp.*, etc..) and the presence of some gramineous species (*Andropogon sp.*) are good indicators for fertility replenishment for farmers.

Gravelly soils (lateritic, Typic Cuirustalfs) can be cultivated for 4 to 5 years. They require 15 to 20 years for fertility replenishment. Farmers report that the production potential of these soils is lower than that of upland rocky soils (Aeric Tropaquepts). Run-off is a major constraint of production for these soils in addition to striga. The advantage of farming these soils is the possibility of using equipment, which can be difficult when those are many stones are.

In contrast plain soils (Typic Ustropepts) can be cultivated continuously when fertilization is available. They also allow the use of equipment (plough, carts, etc.). The length of cultivation for these soils is at least ten years. The time required for fertility restoration is also lower (3 to 4 years). Weeds can be a problem but planting earlier in the cropping season helps to alleviate this constraint. The major constraint with respect to plain soils is the very limited area they comprise in Fansirakoro.

Some lands cannot be farmed where animal are herded, grazed or watered. Fallow lands and areas not cultivated are used as rangelands. Planting of trees required an agreement from the land owner's. Women get land from their husbands. The women utilize trees like Néré (*Parkia biglobosa*), shea butter (*Vitellaria paradoxa*) and baobab (*Adansonia digitata*). Youngsters use mainly the fruits of *Zizyphus mauritiana*.

The use of wild fruits is also regulated. Néré (*Parkia biglobosa*) and Tamarin (*Tamarindus indica*) belong to owner of the cultivated field. But when these trees are located in the fallow land, their harvesting is not regulated and population from the three villages can use them. The harvesting of shea butter (*Vitellaria paradoxa*) is free. The cutting of these trees is forbidden because of the valuable multipurpose uses.

b. Farming systems

Land tenure system in Fansirakoro is typically complex. On the one hand there is a kind of egalitarian access to land for all families; on the other hand there is the historical reality of founding families maintaining a hold on more land over generations. The introduction of cash crop (cotton, tomato and tobacco), the use of animal traction (which requires complete clearing for best efficiency) and the degradation of land under population pressure have aggravated this situation.

Land cannot be sold in Fansirakoro. It can be acquired through patrimonial linkages or through loans. The village chief has the power to settle all land tenure disputes. All villagers have the right to a parcel of land to support their family, but the overall land use is determined by the village chief and by village tradition. An outsider from a neighboring village can gain temporary access to land by a loan from a farmer with surplus land or by a grant from the village chief. However, he cannot plant fruit trees.

Land has important economic and material value due to its capacity to sustain life. It has also a sacred character due to its procreative powers; the ancestors are thought to have made an alliance with the sacred spirits to obtain permission for its use. Specifically, clearing land for agriculture is seen as a sort of sacrilege. Farmers are reluctant to abandon poor agricultural lands. Only 5% of farmers in Fansirakoro are food self-sufficient for the last five years. However, they stated that they would not leave even if given land in another sector or zone. They're felt that they should remain to guard their spirits and tombs.

No individual can claim to own land. The user is only a temporary trustee; land belongs to the past, present and future kinship group, and forms part of the group patrimony or heritage. In Fansirakoro, the extended family owns a piece of land as a collective proprietor. The head of the production unit can distribute parcels to individual family members. Departures from this general model can exist. For example, land near villages which is cleared and manured is too valuable to allot to a another family; this is equally true for flood recession land, land near irrigation water, and other valuable land. Once a family has obtained access to land, the rights can be handed down to succeeding generations. Farmers who want additional land can request it from the village chief or others families. Forceful appropriation of land is strongly resisted.

Farmers in Fansirakoro are bringing more and more land into cultivation, mainly increase with shallow soils and in erosion sensitive upper parts of the catena. From 1996 to 1998, 2.4% more land was brought under cultivation. However, shifting cultivation is being replaced by continuous cultivation; fallow land that was traditionally used to build up soil fertility is becoming rare. The duration of fallow has shortened drastically from 20 years to 4 years. Many households cannot rely anymore on fallow to build soil fertility.

Farmers in Fansirakoro complained about the lack of fertile lands. As a result, they prefer to cultivate the surroundings steep slopes (ranging from 10 to 15%), claiming additional advantages of diminished weed invasion in these fields. The availability of land for cultivation is a major constraint in the village of Fansirakoro and the practice of fallowing is not usual in Fansirakoro because of the scarcity of land.

Mixed farming systems involving cropping and livestock tending associated with off-farm activities are dominant in Fansirakoro. The village of Fansirakoro is essentially agricultural; food and cash crop productions constitute the major activity of people. Cereal grains, sorghum, millet, maize, rice are the main food crops. Cotton, tobacco and tomatoes and to a lesser extent peanut are the main cash crops. Cowpeas, land peas (*Voandzeia subterranea*), cucumber, orrions, potatoes, cabbage and lettuce are also cultivated.

Food crops concern 72.3 % of cultivated land in Fansirakoro and the average food crop area per PU is 3.70 ha. Sorghum is the main staple crop because of the cultivated area and production. It is mainly cultivated in association with cowpeas or with millet. The area cultivated in sorghum and millet represented 47.9 % of cultivated area in 1998. Local varieties such as *Keniké*, *folaba*, *drongo* and *Kedé* are mainly used. Only 20% of farmers are using improved seeds of sorghum. Fertilizers (organic or mineral) are not used on sorghum. Few farmers practice animal traction (mainly ploughing). The low use of animal traction might be explained by the predominance of rocky, shallow soils. Line seeding is used by 40% of farmers and stock management and conservation are not practiced at all. Maize, the main food crop after sorghum, is cultivated on compound fields around the village. Maize represented 14.33% of cultivated land in 1998. The improved variety *Tiemantiè* of *Zamblara* is mostly used. Maize in compound fields receives farmyard manure (household waste and animal feces, etc.). Composting and/or manure production are not usual.

Millet is the third food crop. Rice and fonio (*Digitaria sp*) are secondary crops used to support the main crops. The variety *Pogona* with red seeds is the main variety of fonio found in Fansirakoro. Rice is cultivated in lowlands and mainly by women. Cowpea is the most important legume crop because of the cultivated area and production level. It is cultivated with land peas as a single crop on very small fields. Peanut and Gombo (*Hibiscus esculentus*) are the main crops cultivated by women.

Only men cultivate cotton. Cash crops represent 27.6 % of the cultivated land of Fansira and the average cash crop area per PU is 1.70 ha. They include cotton, tomatoes

and tobacco. Cotton represented 27.6 % of cultivated land in 1998. Improved technologies like improved seeds, ploughing, line broadcasting (spreading seed by hand), weeding, mineral and organic fertilization are applied mainly on cotton. Tobacco cropping by both men and women is done during the dry season around the *Sidjèko* river located 15 km from Fansirakoro. Women help also in the family crops for planting, harvesting and transporting.

Crop yields in the area are very low for dry land farming crops. They are estimated at 6 to 800 kg/ha for sorghum, 900 kg/ha for maize in compounds fields, 200 kg/ha for millet (mainly associated with sorghum), 50 to 200 kg/ha for cowpeas, 100 kg/ha for land peas (voandzou). Farmers are aware of the declining yields of their rainfed crops. They estimated the rate of decline of yields at 100% per year (ie. 2 tons, 1 tonne, 500 kg per year). In contrast, they advocate that yields of tomatoes have been increased because of improved techniques. Crop rotations in the area are sorghum - millet, cotton-sorghum, peanut-millet, sorghum-peanut-millet-sorghum.

The use of inputs (mineral fertilizer, manure) is very limited because of the price of fertilizers and the low level of availability of organic fertilizers. Mineral fertilizers are used for the cotton, maize, tomato and tobacco. Manure is used mainly on the compound fields farmed in maize. Only a third of these areas might receive organic fertilizers. The practice of making of compost does not exist in Fansirakoro. Household wastes are stacked and brought in the fields. Manure is mainly dry feces of ruminants and the free roaming of these animals in the dry season reduces its manure availability.

Practices of water management existing in Fansirakoro include stones lines, physical barriers in waterways, fascines, and planting trees, etc.. Stone lines are applied by many farmers in Fansirakoro even if they are not properly designed and plot size are very small. Several species of trees have been used in Fansirakoro for planting. They include *Azadiracta indica* (neem), *Eucalyptus sp.*, *Acacia albida*, (balazan), *Prosopis juliflora*, *Kaya senegalensis* (caïcedrat) and *Jatropha curcas* ('ourghère). Poughère is mostly used for planting on stone lines.

Livestock is quite important in Fansirakoro. 67% of Production Unit (PU) are involved in livestock tending activities. Ruminants (cattle, sheep and goats) are dominant in the livestock system. Cattle, sheep and goats represents respectively 38.6, 36,6 and 28.6 % of domesticated animals, respective@ oxen are numerous and are 34.88% of the total number of beefcattle. Goats represent 57,8 % of small ruminants. The number of sheep and goats are increasing in the village but cattle are decreasing because of robbery and sales. Farmers tend to invest in animal (cattle, sheep and goats). They hire outsider herders to tend these animals. The herder is paid a fee and given rights to some of the milk of the cows. Herd management and health care is the responsibility of the herder. Donkeys and chicken are also raised in the village. Interactions between crops and livestock are of several forms.

Complementary relationships are essentially related to forage (crop residues) for animals and manure for crops. Animals constitute an asset, which can be used to reduce the impact of crop failure and investment risks. Draught animals are used for cropping and transportation. Important by-products, such as manure, are also considered. Conflicts have developed as population pressure increases causing competition for land use for cropping and livestock.

Agricultural credit in the village of Fansirakoro is provided by OHVN, the main extension institution operating in the area. OHVN credit system is related to cotton production. At village level, the credit is handled by the *ton villageois*. It is thought that social pressures would be used on delinquent members who defaulted. Farmers said that social pressures would force these individual to pay. They reasoned that village elders knew

each individual's capacity for repayment better than any outsider, and that credit would in this way be extended only to individuals who have demonstrated capacity to manage loans.

Credit is given in the form of farm equipment (plough, seeders, etc) and inputs such as fertilizers and pesticides, which are usually promised at the beginning of the cropping season. It is associated usually with cash crop production. In 1997-98 Fansirakoro received sixty bags of mineral fertilizers (20 of urea, 40 of mixed fertilizers) for cotton production. Agricultural credit was higher for the year 1998-1999 and concerned 316 bags of mixed fertilizers, 85 bags of urea and 320 liters of insecticide. The village also received 8 oxen, a cart and 5 ULV. The amount of credit from OHVN has been increasing since 1994. According to the population the village uses mineral fertilizers for vegetable production (3 to 5 bags per agricultural production unit).

Natural resource management technological packages recommended by OHVN concern water management (stone lines and tree planting), improved fallow, living fences, improved corrals and improved organic matter production. The adoption of these improved technological packages by farmers is not very high. For example only 6.4% of PU in Fansirakoro used living fences. These figures are 5%, 8% and 13.3% respectively for improved fallow, composting and improved corrals. Physical methods for water management or soil conservation are getting some interest among farmers in Fansirakoro. Stone lines are used by about 32% of farmers.

Diets in Fansirakoro are based on sorghum and/or millet with peanut sauce and when available meat and fish as source of proteins. Corn and rice are included to a limited extent in the diet of farm families. Corn is considered a garden crop and is frequently consumed fresh during the rainy season because of it is harvested earlier than other crops. The population of Fansirakoro assumed that in the last decade very few of farm families were food self-sufficient (only 5.6%). During years of good rainfall like in 1997-98, that figure can reach 50%. This meant that even in good years 50% of the population cannot provide their own food considering all sources.

c. Evolution of natural resources

Farmers recognized that the state of natural resources in Fansirakoro is changing. For example yields of crops on gravelly soils (shallow soils over laterite -Typic Cuirustalfs) have decreased drastically. This decreasing of yields are related to:

- diminishing rainfall;
- lack of moisture;
- reduction of the density of trees;
- reduction of organic matter in the soil;
- and increased run-off.

Rice was cultivated on the plains, but today farming of millet on these soils is a problem. Maize was cultivated on rocky upland soils; this is not the case today and maize is cropped only on compound plots. Many trees and grasses have disappeared or have become less in number on the landscape. Trees that are disappearing are *Oxyanthera abyssinica*, *Prosopis africana*, *Cordia pinnata*, *Burkea africana*, *Kaya senegalensis*, *Pterocarpus erinaceus*, *Annona senegalensis*, and *Azalia africana*. Grasses like *Cymbopogon giganteus*, *Loudetia sp.* and *Hyppathenia sp.* have also disappeared.

Farmers noticed that some grasses mainly weeds like *Digitaria sp.*, *striga sp.*, *Pennisetum pedicellatum*, *Loudetia sp.*, *Andropogon pseudapricus*, etc.) are becoming dominant. Trees species that increased in number are *Bauhinia sp.*, *Terminalia sp.*, *Acacia*

macrostachias, Dicrostachys glomerata, and Detarium micricarpum. Causes for the evolution of natural resources as related by farmers are:

- aridity of climate;
- **diminishing rainfall;**
- **uncontrolled** cutting of trees by herders;
- cutting of trees by farmers for charcoal and **firewood;**
- controlled cutting of trees for **cultivation;**
- and demographic pressure.

The causes of the **degraded state** of the natural resources are interrelated and can be **illustrated** by a problem tree. Farmers in Fansirakoro are resource poor and they have a **deficit** in cereal production. The **interaction between** population growth and the need of cultivated **lands to meet subsistence requirements** leads to the **reduction** of **fallow** periods in Fansira below **levels** necessary to **maintain** soil **quality**. Cultivation is expanding **onto** marginal **soils** that more **fragile and** degraded **rapidly**. Growing markets for **farm commodities** as well as for consumer goods are **putting** more pressure on the villages' natural resources.

Most of the total farm household **income** comes **from** non-trop sources. Research on adoption and **diffusion** of farm **technologies** has revealed that criteria like cash flow, food **security**, **labor burden** and social **acceptance** play a role in the **acceptability** of new technologies, in addition to **immediate** economic **and/or** net **present** value of future **benefits**. The **lack** of capital **limit** the potential of farmers to participate in yield **stabilizing** or yield improving technologies. Tree cutting for **firewood** and charcoal is also **common** among **villager** to generate some cash. Tomato and tobacco are the main cash **crops**, in addition to **cotton**. However, the **lack** of water **sources** for **tobacco** and tomato and the know-how needed for **cotton cropping** **limit** the potential of these **crops** for **income** generation. **Natural** resource degradation like **decreased** soil **fertility**, soil erosion and excessive **runoff** of water are **likely** to exacerbate this situation (Figure 1). **Manuring** can contribute to sustainable production **increases** on the alluvial and **acidic soils**, which have low **buffering capacity**, in that it increases the **soil buffering capacity**, and thereby leads to better **nutrient** use efficiency. However, the **lack** of **adequate** livestock husbandry **limits** the **manure** supply. **Likewise**, the **lack** of **carts** for transportation of **manure** to distant fields in the **bush** land is also a **constraint**.

The main **agricultural** production **constraints** according to farmers are related to soil and water conservation and management. **Rainfall** has **diminished** drastically and it is **not** **regular** in **space** and time. Run-off has also become important in the **landscape**, so has the leaching of **mineral** from organic matter. Water **infiltration** in the soil is very low. Soil loss through erosion is **alarming** with **gullies**. **Vegetation cover** is also very poor in the area.

Farmers **maintained** also that the **fertility** of soil is very low. They were **informed** on **improved technologies** for **organic** matter production (compost and **manure**), but these packages are **seldom** applied. **Reasons** for the low level of **adopting** extension packages **stated** by farmers are **given** for food crops (Table 1) and cash **crops** (Table 2). The **lack** of **information** and **insufficient** equipment are important as **constraints**. Roaming of **animals** during the dry season is the **common** practice in Fansirakoro because of **lack** of forages and **drinking** water. **Also**, young males are **not** available for tending herds because they move to other villages for **tobacco cropping**. The **lack** of **equipment** for compost or manure handling (carts, donkeys, etc) is also a **constraint**.

Table 1: Constraints for Using Some Food Crop Technologies

Technology and reasons of adoption	Reasons for not adopting	Farmers' current practices
<u>Use of organic fertilizers</u>	-65 % lack information about organic fertilizer production -30 % lack of a mean of transportation -25 % Access to fields on mountains is very difficult	Collecting household waste
<u>Use of mineral fertilizers</u> -50 % Soils are poor - required for for optimum production	- 50 % high cost of fertilizers -10% can't grow cotton	<u>Cotton cropping as a mean to get access to mineral fertilizers</u>
<u>Improved seeds (20 %)</u> - 15% earliness allows varieties to close their cycle. -10 % High production	-50% access is difficult (lack of information) -30% disease prone because of the lack of resistance - bad food quality	<u>Use of improved seeds</u>
<u>Line seeding</u> 40 %-40% optimum density for high production	-50% landscape is a problem -30 % lack of equipment	<u>Line seeding</u>
<u>Stock preservation</u>	-100% lack of information -chemical products unavailable	Preservation of harvest in stacks, panicles and spikes
<u>Stock management</u>	-80% advertised method does not seem to be appropriate for us -50% high costs	Traditional management

Organic fertilizers like manure, household wastes are not used in Fansirakoro either for food or cash crops. Constraints according to farmers are the lack of information, the lack of equipment for manure transportation and the relief of the landscape in and around the village. Farmers are aware of advantages of using yields increasing or yield stabilizing technologies. For example, many are not using chemical fertilizers because they are not cotton growers. Cotton growing is becoming a current strategy in Fansirakoro to get access to inorganic fertilizer and other inputs.

Table 2: Constraints for Using some Cash Crop Technologies

Reasons of adoption	Reasons for not adopting	Farmers' current practices
<u>Organic fertilizers</u>	<u>Organic fertilizer 100 %</u> -65 % lack of information on preparing organic fertilizers -30 % lack of transportation equipment -25 % Access to hilly fields difficult	<u>Collecting household waste</u>
<u>Mineral fertilizers</u> - 40 % poor soils - required for higher production	10% not cotton growers	<u>Using mineral fertilizers</u>
<u>Line seeding</u> - 40% rational use of cultivated area - increasing plant density -allow the use of other animal traction equipment	<u>Line seeding 60 %</u> -60% lack of equipment (seeder)	Use of cord
<u>Herbicide</u>	<u>Herbicide</u> -100% Costs too high	<u>Herbicide</u>
<u>Pests and disease control 90 %</u> -90% High frequency dplant pest and disease -required for high level of production	<u>Traitement phytosanitaire</u> -10% not cotton growers	Use of chemical products

6. Recommendation Domains

A recommendation domain is information that farmers can use to improve or to maintain the productivity of their resources and or their farming systems. Depending on constraint potentials and constraints for adopting specific technologies, and farmers' needs (recycling of organic matter by composting or manure production, etc.), PUs in Fansirakoro can be categorized in two recommendation domains based on farmers circumstances and problems and practices. Recommendation domains are not necessarily the same for all technologies that are developed. Different recommendation domains may be desirable for different problems and related solutions. In the process of on-farm research, recommendations can get redefined after the preliminary diagnosis.

The needs for interventions identified by farmers are:

- improving water and soil management (stone lines, small dams, etc.);
- intensifying the production of organic matter (compost, improved corrals);
- reinforcing complementary relationships between cropping and livestock systems (forage relationship, manure relationship, etc.);
- developing and implementing a community based natural resource management strategy at village level.

Stone lines have been introduced in Fansirakoro in 1994 on a community basis. The lack of labor resources at farm level during the dry season because of labor migration for survival has been a handicap for the continuity of this action. Uncontrolled use of vegetation by the population of Fansirakoro and neighbouring villages (Fansirakoro and Fabougoula) remains a big concern for the preservation of natural resources because of poverty.

Recommendation domain 1

This group which represents 30% of farmers (PUS) in Fansirakoro. Resources available are important labor force, the availability of equipment for animal traction and that of cattle (> 5 head) in addition to oxen, goats and sheep. Because of its resources, the group can adopt yield improving and yield stabilizing technologies like:

- improving organic matter production and management;
- utilizing improved for increasing food crop production;
- diversification of cropping systems and/or farming systems;
- integrating forage crop production and improving livestock production;
- improving the management of cropping systems;
- soil and water management technologies.

Recommendation domain 2

This group comprises 70 % of farmers. Resources are very limited for this group. However, this group can use yield stabilizing and even yield improving technologies. Very evident results might require reversing the aversion of this group to adopting improved technologies. The labor force available for this group is very low, and most of the time, equipment is lacking or incomplete. Livestock available are small ruminants and courtyard chicken. Potential technologies the group can use are the following:

- Food crops diversification;
- Utilizing improved seeds;
- Recycling organic matter through composting;
- Improved cropping systems management practices;
- Improved crop/livestock interaction through small ruminants;
- Intensifying vegetable crop production if water is available.

7. Conclusion

Farmers in Fansirakoro are resource poor and farmers' actual practices are likely to increase costs per unit of production because of the continued degradation of the natural resource base (land) and by the extension of cultivation onto marginal soils. The immediate priority should be placed on low-cost runoff management systems that are well adapted to the situation of Fansirakoro. Participative technology adaptation should concern conserving the Land, increasing yield and/or stabilizing yield.

**THEME 2 : SOIL AND WATER
CONSERVATION**

Improving Food Crop Production in Subsistence Farming System in Fansirakoro and N'tétoukoro

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1. Justification

This consists of comparing the effect of mixed fertilizers as extender of manure with the farmers' practices without fertilization or only manure. The assumption was that the physical combination of mixed fertilizer with manure will take advantage of the physical properties of the manure in providing an environment conducive for root growth.

2. Objectives

- to compare effects of combining mixed fertilizers with manure (T3), manure only (T2) and without fertilizers (T1) on yields of sorghum;
- to evaluate the economic performance of the three management nutrients systems.

3. Methodology

The test was conducted in two villages (Fansirakoro and N'tétoukoro) with 10 farmers in each site.

It consist of the following:

- control (no fertilization)
- 3 tons of farmyard manure
- 3 tons + NPK mixed together (25% equivalent applied manure).

4. Results

Data used in the analysis concerned one village (N'tétoukoro) and five (5) out of seven (7) who performed the test correctly. Two farmers (farmers number 2 and 6) have been eliminated because of inaccurate data.

The variables used in the analysis are the following (Table 1):

- Variable 1: (NPOQ) number of poquets (planting hill) per hectare (ha)
- Variable 2: (NPLT) number of plants/ha
- Variable 3: (NEPI) number of panicles, kg/ha
- Variable 4: (PEPI) panicle weight, kg/ha
- Variable 5: (PGRA) grain weight, kg/ha
- Variable 6: (GREP) Ratio grain/panicle

Annex**List of observations**

N°	Farmers	Treat	NPOQ	NPLT	NEPI	PEPI	PGRA	GREP
1		1	13600	24267	21733	1581	1247	0.79
1		2	12133	22533	22000	2011	1468	0.73
1		3	12133	28133	25467	2373	1627	0.69
*	2	1	19467	39067	39067	2789	2245	0.80
*	2	2	26133	67067	65733	2761	2024	0.73
*	2	3	19333	41067	38800	2547	2027	0.80
3		1	20667	50400	50133	2365	1821	0.77
3		2	21733	59867	45200	2355	1824	0.77
3		3	24133	54400	47600	2645	2075	0.78
4		1	23467	68133	47600	1211	900	0.74
4		2	22400	66267	56000	884	631	0.71
4		3	24667	69867	52533	170s	1272	0.74
5		1	18533	42400	29067	912	784	0.86
5		2	22133	55600	47600	987	853	0.86
5		3	18667	46933	41467	1187	819	0.69
*	6	1	13467	24267	23333	1425	995	0.70
*	6	2	13333	26800	25867	1223	787	0.64
*	6	3	13067	23333	23200	1019	768	0.75
7		1	20533	45467	42933	1312	1003	0.76
7		2	21600	40667	35600	987	736	0.75
7		3	22933	54133	50400	2373	1755	0.74

Initial analysis from the seven farmers fields (farms were replications)

	NPOQ	NPLT	NEPI	P E P T	PGRA	GREP
Control (T1)						
average	18533	42000	36266	11656	1284	0.78
STD	3736	15292	11571	672	543	0.05
cv%	20	36	31	40	42	6.52
maximum	23466	68133	50133	2789	2245	0.86
minimum	13466	24266	21733	912	784	0.70
Manure (T2)						
moyenne	19923	48400	42571	1600	1188	0.74
écart-type	5160	18468	15810	763	572	0.07
CV%	25	38	37	47	48	9.01
maximum	26133	67066	65733	2761	2024	0.86
minimum	12133	22533	22000	884	630	0.64
Manure + fertilizers (T3)						
moyenne	19276	45409	39923	197s	1477	0.74
écart-type	5098	16135	11690	670	538	0.04
CV%	26	35	29	33	36	5.71
maximum	24666	69866	52533	2645	2074	0.80
minimum	12133	23333	23200	1018	768	0.69

***** ANALYSE DE VARIANCE *****

DONNEES DE 5 PAYSANS

ANALYSE DE LA 1re VARIABLE : Nbre poquets/ha (NPOQ)

INTERACTION TRAITEMENTS*BLOCS

SCE test de TUKEY = %4747698.00 PROBA = 0.1583
ANALYSE DE VARIANCE

	S.C.E.	DDL	CARRES	MOYENS	TEST F	PROBA	E.T.	C.V.
VAR.TOTALE	%244717072.00	1	4	17479790.00				
VAR.FACTEUR 1	3301952.00	2	16	50976.00	0.72	0.5172		
VAR.BLOCS	%223182256.00	4	5	75564.00	24.48	0.0002		
VAR.RESIDUELLE 1	%18232864.00	8	2279108.00				%1509.67	7.6 %

TABLEAU DES MOYENNES

MOYENNE GENERALE = 19955.56

MOYENNES FACTEUR 1 = FERTILISATION

F 1 : 1 (T1) 2 (T2) 3 (T3)
19360.00 20000.00 20506.67

MOYENNES BLOCS = PAYSAN

F 2 : 1 (P1) 2 (P2) 3 (P3) 4 (P4) 5 (P5)
12622.22 22177.78 23511.11 19777.78 21688.89

ANALYSE DE LA 2e VARIABLE : Nbre plts/ha (NPLT)

INTERACTION TRAITEMENTS*BLOCS

SCE test de TUKEY = %578518.31 PROBA = 0.8851
ANALYSE DE VARIANCE

	S.C.E.	DDL	CARRES	MOYENS	TEST F	PROBA	E.T.	C.V.
VAR.TOTALE	%3193808600.00	14	22819184.00					
VAR.FACTEUR 1	%53079552.00	2	2563776.00	1.07	0.3886			
VAR.BLOCS	%2942585100.00	4	735646270.00	29.70	0.0001			
VAR.RESIDUELLE 1	%198144000.00	8	24768000.00				%4976.75	10.2 %

TABLEAU DES MOYENNES

MOYENNE GENERALE = 48604.44

MOYENNES FACTEUR 1 = FERTILISATION

F 1 : 1 (T1) 2 (T2) 3 (T3)
46133.34 48986.66 50693.33

MOYENNES BLOCS = PAYSAN

F 2 : 1 (P1) 2 (P2) 3 (P3) 4 (P4) 5 (P5)
24977.78 54888.89 68088.88 48311.11 46755.56

ANALYSE DE LA 3e VARIABLE : Nbre épis/ha (NEPI)

INTERACTION TRAITEMENTS*BLOCS

SCE test de TUKEY = %1057751.00 PROBA = 0.8686
ANALYSE DE VARIANCE

	S.C.E.	DDL	CARRES	MOYENS	TEST F	PROBA	E.T.	C.V.
VAR.TOTALE	%1827116930.00	14	130508352.00					
VARFACTEUR 1	%68098304.00	2	34049152.00		0.99	0.4161		
VAR.BLOCS	%1482820610.00	4	370705150.00		10.74	0.0030		
VAR-RESIDUELLE	1 %276198020.00	8	34524752.00				%5875.78	14.3%

TABLEAU DES MOYENNES

MOYENNE GENERALE = 41022.22

MOYENNESFACTEUR1 = FERTILISATION

FI: 1 (T1) 2 (T2) 3 (T3)
38293.33 41280.00 43493.; ,
MOYENNES BLOCS =PAYSAN

F 2 : 1 (P1) 2 (P2) 3 (P3) 4 (P4) 5 (P5)
23066.67 47644.44 52044.44 39377.78 42977.78

ANALYSE DE LA 4e VARIABLE : Pds épis kg/ha (PEPI)

INTERACTION TRAITEMENTS*BLOCS

SCE test de TUKEY = 8143.95 PROBA = 0.7642
ANALYSE DE VARIANCE

	S.C.E.	DDL	CARRES	MOYENS	TEST F	PROBA	E.T.	C.V.
VARTOTALE	5715564.00	14	408254.56					
VAR-FACTEUR1	1190281.00	2	595140.50		7.74	0.0137		
VAR.BLOCS	3910471.50	4	977617.88		12.72	0.0018		
VARRESIDUELLE	1 614811.50	8	76851.44				277.22	16.7%

TABLEAUDES MOYENNES

MOYENNE GENERALE = 1659.38

MOYENNESFACTEUR1 = FERTILISATION

F1: 1 (T1) 2 (T2) 3 (T3)
1476.27 1444.53 2057.33
MOYENNES BLOCS =PAYSAN

F2: 1 (P1) 2 (P2) 3 (P3) 4 (P4) 5 (P5)
1988.44 2455.11 1267.56 1028.44 1557.33
test de NEWMAN-KEULS - seuil = 5%

FACTEUR 1 : FERTILISATION

NOMBREDE MOYENNES 2 3
VALEURSDESPPAS 404.70 500.47
F1 LIBELLES MOYENNES GROUPES HOMOGENES
3 T3 2057.33 A
1 T1 1476.27 B
2 T2 1444.53 B

ANALYSE DE LA 5e VARIABLE : Pds grain kg/ha (PGRA)

INTERACTION TRAITEMENTS*BLOCS

SCE test de TUKEY = 1186.81 PROBA = 0.8825
ANALYSE DE VARIANCE

	S.C.E.	DDL	CARRES	MOYENS	TEST F	PROBA	E.T.	C.V.
VARTOTALE	3172283.20	14	226591.66					
VARFACTEUR 1	494001.00	2	247000.50		5.08	0.0376		
VAR.BLOCS	2289175.80	4	572293.94		11.77	0.0023		

VAR.RESIDUELLE 1 389106.50 8 486 38.3 220.54 17.6%

TABLEAU DES MOYENNES

MOYENNE GENERALE = 1254.22
 MOYENNES FACTEUR 1 = FERTILISATION

F 1 : 1 (T1) 2 (T2) 3 (T3)
 1150.93 1102.40 1509.33
 MOYENNES BLOCS = PAYSAN

F 2 : 1 (P1) 2 (P2) 3 (P3) 4 (P4) 5 (P5)
 1447.11 1906.67 934.22 818.67 1164.44
 test de NEWMAN-KEULS - seuil = 5%

FACTEUR 1 : FERTILISATION

NOMBRE DE MOYENNES 2 3
 VALEURS DES P.P.A.S 321.96 398.15
 FI LABELLES MOYENNES GROUPES HOMOGENES
 3 T3 1509.33 A
 1 T1 1150.93 B
 2 T2 1102.40 B

ANALYSE DE LA 6e VARIABLE : Rapport gra/e i (GREP)

INTERACTION TRAITEMENTS*BLOCS

SCE test de TUKEY = 0.00 PROBA = 0.185
 ANALYSE DE VARIANCE

	S.C.E.	DDL	CARRES	MOM	NS	TEST F	PROBA	E . T .	C.V
VAR.TOTALE	0.04	14		0.00					
VAR.FACTEUR 1	0.01	2		0.00		1.83	0.2217		
VAR.BLOCS	0.01	4		0.00		1.23	0.3695		
VAR.RESIDUELLE 1	0.02	8		0.00				0.05	6.2%

TABLEAU DES MOYENNES

MOYENNE GENERALE = 0.76

MOYENNES FACTEUR 1 = FERTILISATION

F 1 : 1 (T1) 2 (T2) 3 (T3)
 0.79 0.77 0.73
 MOYENNES BLOCS = PAYSAN

F 2 : 1 (P1) 2 (P2) 3 (P3) 4 (P4) 5 (P5)
 0.73 0.78 0.73 0.80 0.75

Effect of Manure and P-Source Fertilizer on the Optimization of Soil Water and Nutrient Use For the Main Cropping System in Senegal Peanut Basin

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Abstract

A four-year national programme is underway to boost the food and cash crop production. P and Ca soil amendment using natural resources based materials is one of the strategies defined. A network of randomized complete block design experiments was installed within each of the three main cropping systems in the Senegal Peanut Basin. The treatments consist of phosphogypsum and phosphate rock mix, and manure, used separately or combined in order to investigate the optimization the crop water and nutrient use. The monitoring deal with soil fertility change, crop water and nutrient water balance, and yield components. For the experiment installed at Nioro Research Station in 1997 within the peanut/corn cropping system, the important Ca movement observed within the profile is strongly related to the amount of Ca added for each treatment. Deep water percolation is also observed despite the moderate amount of the annual rainfall, and regardless of the treatment. Corn and peanut yields obtained are low. The treatments were not significantly different.

1. Introduction

In the Senegal peanut basin, fallow practices have almost disappeared from the farmer's land use system. This situation is strongly related to the introduction of peanut as a cash crop, but also results from an increased demand for food crops by an increasing population. The high pressure on the naturally fragile soils combined with the drought problem observed during the last 30 years is detrimental to the annual and perennial vegetation cover. Therefore, through soil organic matter loss and acidification due to continuous cropping and/or grazing, the food production system has lost its resilience. In most farmer's field, the degradation of soil water characteristics favors an important deep water percolation beyond the rooting depth, even under moderate rainfall conditions. This also increases nutrient leaching risks. Manure applications and plowing are very efficient in reducing the water and nutrients loss through deep percolation by promoting a rapid crop root growth (Cissé, 1986).

Many studies have confirmed the efficiency of natural rock phosphate (RP) amendment at an application rate of 400 to 500 kg/ha every 4 to 5 years to correct soil P deficiencies. On soil with low pH, the agronomic efficiency of the rock phosphate ranges from 82 to 91 % compared with triple super phosphate (Bationo et al, 1990). This value depends on the chemical characteristics of the rock phosphate mines for which comparison results of the study are available and soils to which it is applied (Ndiaye, 1978 ; Cissé, 1980).

However, for phosphogypsum (PG) or the combination of RP and PG now being used in Senegal in the national 4-year program, there is little information in terms of agronomic value or soil P and Ca amendment efficiency. The on-going experimentation comparing those two mineral compounds is set to focus on that aspect. Assuming a positive effect of the combination of RP and PG, the objective of this study is to

analyze the main cropping systems for the efficiency of applying combined P source material and manure to a degraded soil to optimize water and nutrient plant uptake in order to attain a sustainable crop production increase.

2. Materials and methods

a. Experimental sites

The sites were selected according to the existing main cropping systems. Within the Peanut Basin, the improvement of food security can be achieved in three cropping systems. In the northern part of this agroecological zone, peanut followed by millet is the predominant if not the unique crop rotation, whereas in the southern part, peanut followed by corn is a common practice. In the low lands of the latter zone, continuous rice is practiced.

One site for a long term experiment was selected in each of these representative crop systems: one site for peanut/millet rotation at Ouadior (Gossas Department) in the north, two sites for peanut/corn rotation in Nioro area (one at the ISRA Research Station and one on-farm field near the station), and one site for continuous rice in the Koutango valley (west part of the Nioro Department).

All the selected sites under the upland conditions are continuously cropped fields with degraded soil fertility status, as illustrated by Nioro soil analyses data (Table 1).

Table 1: Soil physical and chemical characteristics (0-10 cm). Nioro

pH _{KCl}	Clay + Silt %	Sand %	Total C %	C/N %	Ca meq/100g	T	S/T *100	Total P λ	P Olsen (ppm)
4.9	7.9	92.2	2.5	9.2	0.6	1.6	64.5	0.2	28.5

b. Treatments

The five treatments compared are shown in Table 2. For cropping systems where corn or rice are involved, plowing is performed when implementing the treatment, including the control. In fact, these two crops require deep tillage in order to express their potential. For the peanut/millet system, only a shallow hoeing is applied to prevent fertilizer loss from wind blow.

Table 2: Treatment description in the different cropping systems

Crop rotations	Treatments				
	T1	T2	T3	T4	T5
Millet/peanut	NK	NPK	O.M.	RP+PG	O.M. + RP+PG
Corn/peanut	P +NK	P + NPK	P + O.M.	P +RP + PG	P+O.M. + RP+PG
Continuous rice	P +NK	P + NPK	P + O.M.	P +RP + PG	P + O.M. + RP+PG

N and K for T1, and N, P and K for T2 are applied annually as urea, ammonium

phosphate or KCl accordingly, the recommended rates are applied for the different crops. T3 consists of manure application at the rate of 5 tons/ha every two years for the 2 first cropping systems, and at 3 tons/ha for the continuous rice system, whereas T4 refers to the application at the rate of 700 kg/ha every four years of RP and PG mix. Last, T5 is the combination of T3 and T4.

For all treatments from T3 to T5, N and K have been added on an annual basis prior to sowing. The experiment was installed at Nioro station in 1997 does not include the T2 treatment, therefore only four treatments are compared.

The experimental design is a randomized complete block design with five treatments repeated four times

The varieties used for the different crops are as follows:

for peanut, variety 55-437 at Ouadiour for short cycle duration (maturity at 90 days after sowing), variety 73-33 at Nioro sites for 105 DAS or medium cycle

for corn, var. Synthetic C (90 DAS)

for rice, upland rice variety DJ-68 4D (maturity at about 90 DAS). Besides this rice variety, the farmers were provided with two other salt tolerant varieties (Rock 5, and Var1). The agronomic behavior of those varieties cultivated according the farmers' practices in the bottom of the valley in submerged conditions have also been evaluated for general assessment of the Koutango lowlands with respect to rice production. In the farmer rice field, six microplots were randomly harvested for yield determinations.

c. Measurements and monitoring

Sites characterization

Soil samples have been collected for the characterization of the sites; Ouadiour, on-farm site at Nioro, and Koutango. For the on-station experiment at Nioro installed in 1997, site characterization data done in 1995 (Agetip, 1995) are used. Soil sampling was also done after the corn harvest in December 1997. All the experimental plots have been sampled at the following depths (0-10, 10-20 and 20-40 cm). Some of the laboratory analysis results that were available are presented in this report.

Soil water balance

This monitoring was done to investigate plant water uptake but also for the purpose of nutrient balance. Soil water content in the soil profile is measured once a week at Nioro station site, and once every ten days elsewhere. Three methods are used: neutron probe, and TDR probe at Nioro station site, and the auger method elsewhere. Access tubes for neutron probe readings are installed at the depth of 265 cm; i.e. deeper than the maximum crop root depths. As for the TDR method, the probe installation depth is limited by the probe length provided (120 cm). Concerning the soil water content measurement method using the auger, the depth of augering is limited by the wetting front as it advances in the profile during the rainy season. Tensiometers are used to determine the soil water suction at the depth supposed to be the maximum rooting depth which is about 150 cm in sandy soils for peanut (Chopart, 1980). The longest tensiometers tube available are 100 cm long. This limited the actual field installation depth for all experimental plots to 100 cm for plots having an installed access tube, and 85 cm for the other plots. Daily measurements readings started in 1998, but late (on september 23 until november 11) due to equipment availability.

The water balance monitoring was not conducted for the on-farm experiment at Diamaguene site (near Nioro Research Station).

The soil water balance equation stated below allows the determination of the soil plant evapotranspiration for specified time increment during the cropping season.

$$R - D - r + \Delta S = ETR$$

R = rainfall, D = drainage, r = runoff, ΔS = variation of stock, and ETR = evapotranspiration. All these components are expressed in mm of water.

For drainage estimation, Darcy's law was used. Soil hydraulic conductivity was calculated using existing soil water characteristic studies for Nioro site (Cissé et al. 1990).

- classe A; A + L = 20 % $K(\theta) = 7.54 \cdot 10^9 \cdot \theta^{13.270}$
- classe B; A + L = 21.5 % $K(\theta) = 2.31 \cdot 10^{10} \cdot \theta^{14.55}$
- classe A; A + L = 20 % $K(\theta) = 6.29 \cdot 10^{10} \cdot \theta^{15.708}$

where A + L = clay + silt content; K = hydraulic conductivity; θ = volumetric water content.

Nutrient balance

This is closely related to soil water balance in general, and to soil water stock and drainage components in particular. It requires the use of the tensiometers to sample soil solution at specified depths. Weekly soil solution samples have been taken, starting in late September. The nutrients of interest analyzed are nitrates, ammonium, and calcium. The results are not yet available.

The nutrients lost through drainage, as part of the nutrient balance components, will be calculated by multiplying the water drainage and the chemical concentration of the different elements analyzed.

Soil samples with depth at the beginning and at the end of each cropping season plant samples at harvest will be collected for analysis. This will allow the determination of nutrient dynamics in root zone and plant nutrient uptake.

Plant sampling

Plant samples were collected at flowering/pegging stage, around 60 days after sowing for foliar diagnosis. The sampling from each plot occurred after noticeable leaf chlorosis was observed on few treatment plots. Analysis of the plant samples is done for the following elements: N, P, K, P, Ca. The plant analysis results are presented.

Field operations

The multi-location experiment started in 1997 on two sites; i.e. Koutango (continuous rice) and Nioro (peanut/corn rotation at the research station). The other sites were implemented in 1998. The cropping operations are presented (Table 3)

Table 3 : Field operation scheduling in the three selected sites.

Operation	Nioro		Koutango		Ouadiour
	Corn (1997)	Peanut (1998)	Rice (1997)	Rice (1998)	Peanut (1998)
RP, PG or Lime application	06/30		07/19	08/10	07/23
Plowing	06/30	06/23	07/22	08/10	-
Sowing	08/05	07/20	07/24	08/21	08/5
N-K Application		07/27		08/21	08/05
Thinning	08/05	-	07/31	09/17	-
Pre-emergence weeding	-	-	-	-	08/06
1 st Weeding	08/22	07/27	08/19	09/15	08/15
1 st Urea application	09/05	-	08/19	09/17	-
2 nd Urea application	09/20	-	09/14	10/02	-
2 nd Weeding	09/10	08/22	09/19	10/01	09/05
Bedding	09/10				-
Harvest	11/3	11/5	11/15	10/26	11/5

Rainfall input

Rainfall patterns are different for the 2 years (1997 and 1998) in Figure 1.

In fact, we have experienced **one** early rainy season in 1997 as opposed to a **late** rainy season in 1998. At Nioro, the total **annual** rainfall is **about** the **same** for the 2 cropping seasons (580 mm). However, while the rainy season started early **June 1997**, the **first** important rain was recorded **late July 1998**. Although characterized by a rather short rainy season, the 1998 cropping season has a **much** better **rainfall** distribution. A long drought period (**over 30 days**) occurred early **during** the 1997 cropping season, causing a severe plant water stress, while in 1998 there **was** no major water stress problem, **except** at the **crop** maturity phase.

At **Koutango** **unlike** at Nioro or Ouadiour, heavy storms were recorded (160 mm on **August 23 1997**, and 100 mm on September 1998). **Even** though the **soil** vegetation cover at that time was **well** established, a important part of the water **from** this **rainfall** event is lost through **runoff**; the **soil** profile being near saturation at this time of the rainy season. The positive aspect is the important **input** water to **refill** the **Koutango** river valley.

Data interpretation

This **concerns** the **yield** data, and the nutrients and water data. For most data, ANOVA methods **will** be implemented to compare treatment **effects**, whenever it is possible. Otherwise, **comparison** of **mean** will be used.

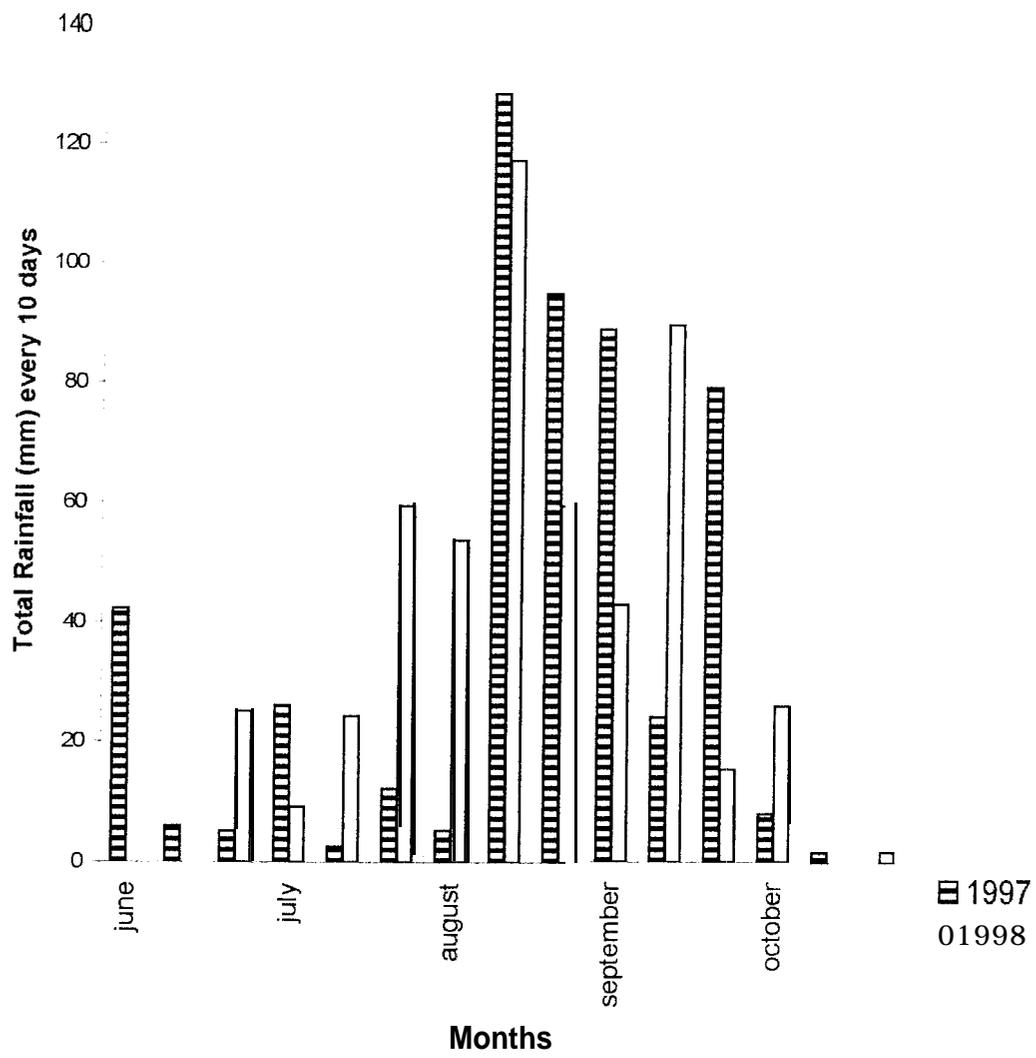
Most of the experiments have started in 1998. Therefore, **only** partial data are available.

3. Results and Discussion

a. On-Station experiment at Nioro

The **yield** components data (**corn** in 1997, and **peanut** in 1998) are presented in Table 4. For **corn**, the ANOVA indicates no **significant effect** on grain yield or **stalk**, despite the **difference** in **mean** between the control and the other treatments. This is largely due

Figure 1: Niuro cumulative rainfall - 1997 and 1998



to important variability within treatments. The corn grain yields obtained are low but higher than those obtained for phosphogypsum efficiency study (also presented in this workshop). It is **assumed** that the **manure** application was the key factor to that **difference**. The soils samples collected **from all** plots down to the depth of 40 cm indicates an enrichment of the **nutrient** content (Table 5), but also a downward movement of **elements such** as Ca (Figure 2).

Table 5: Soil chemical analysis results **after** harvest in 1997. Nioro

Samples	Soil depth (cm)	pHwater	PHKcl	Ca Mg S T				V %
				(mec/100)				
T1 control	0-10	5.0	4.4	0.5	0.1	0.7	0.9	73.3
	10-20	5.2	4.3	0.5	0.1	0.7	0.9	76.5
	20-30	5.0	4.2	0.7	0.3	1.0	1.3	78.3
T2	0-10	5.2	4.6	0.7	0.1	0.8	0.8	98.0
	10-20	4.9	4.3	0.6	0.1	0.8	0.8	84.5
	20-40	4.9	4.2	0.8	0.3	1.0	1.2	82.7
T3	0-10	5.7	5.0	0.6	0.3	1.0	1.1	93.7
	10-20	5.3	4.3	0.5	0.2	0.7	0.9	76.5
	20-30	5.0	4.2	0.7	0.3	1.0	1.3	67.0
T4	0-10	5.3	4.9	0.8	0.2	1.1	1.2	84.3
	10-20	5.1	4.5	0.6	0.2	0.9	1.0	74.0
	20-30	5.0	4.3	0.8	0.2	1.2	1.6	73.3

For peanut in 1998, the plant population was close to the optimum in all plots. The overall **mean** yields are good **compared** to the average yield observed this year. However, no **significant** treatment **effect** for **any** yield **component** was obtained through the ANOVA. **Around** the middle of the rainy season, plant **chlorosis** was observed. Plant samples collected on **each** plot were analyzed. The foliar **diagnosis** results (data not presented) show no **significant difference** between treatments.

Table 6: Yield Components at Nioro Station in 1997 and 1998

Treatment	col-n 1997				Peanut 1998		
	Stand	Stalk	Grain	Plant Population	Pod + hay	Hay	Pod
T1	16800	1800	712	83330	4000	2575	1420
T2	33230	3030	1740	82240	3750	2120	1640
T3	34690	3460	1820	91980	4590	2780	1810
Mean	36420	3140	1880	90620	4480	2540	1940
Sign. Level	NS	NS	NS	NS	NS	NS	NS
cv (%)	32	35	45	14.8	13.4	18.3	9.0

From the soil water monitoring **done during** 1998 growing season, changes in water content in the profile are shown (Figure 3a et 3 b). Two major results **can** be **drawn** from these figures.

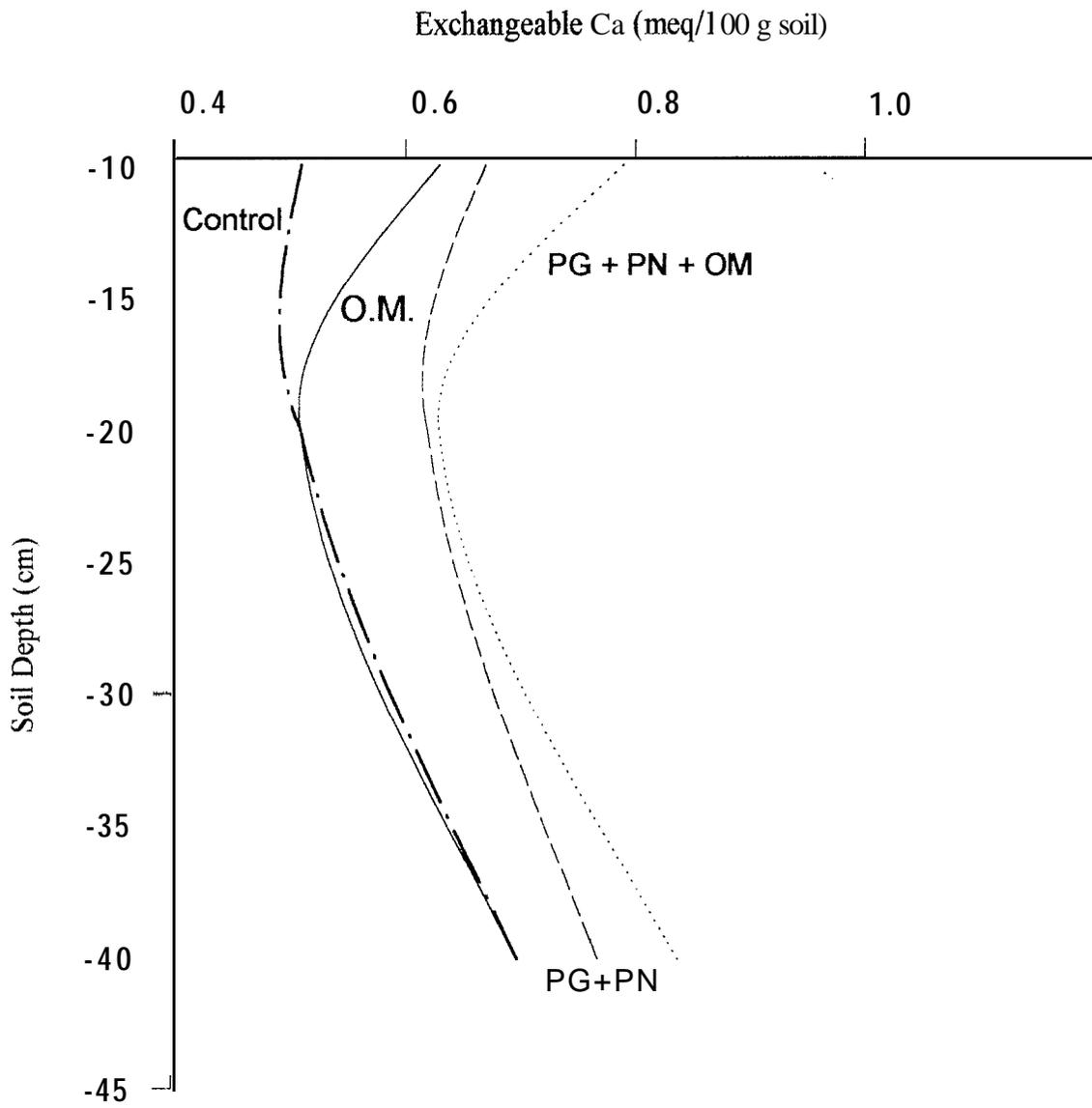


Figure 2. Ca dynamics in the soil profile at Niroo Station. Corn 1997

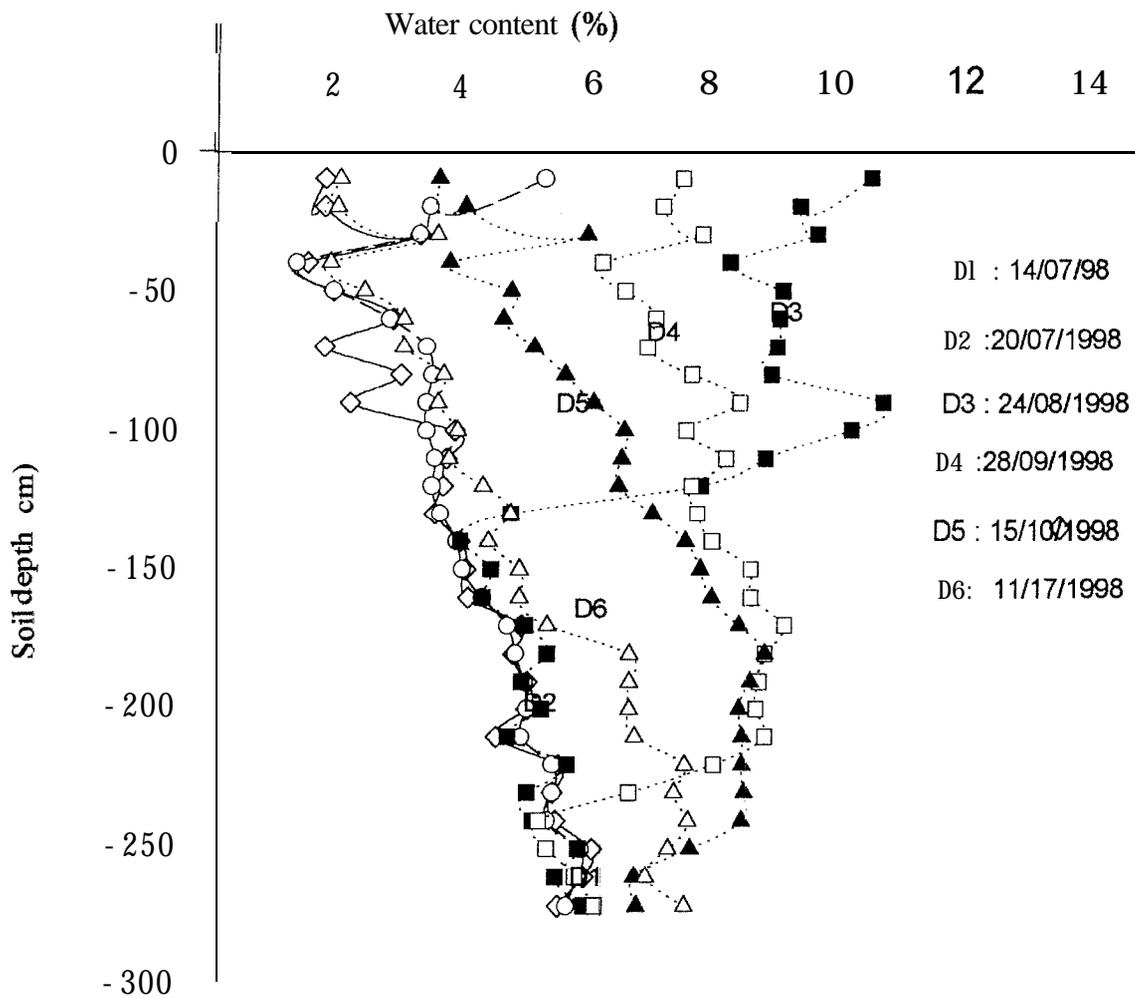


Fig 3a: Change in soil water content in the profile

Treatment: Control

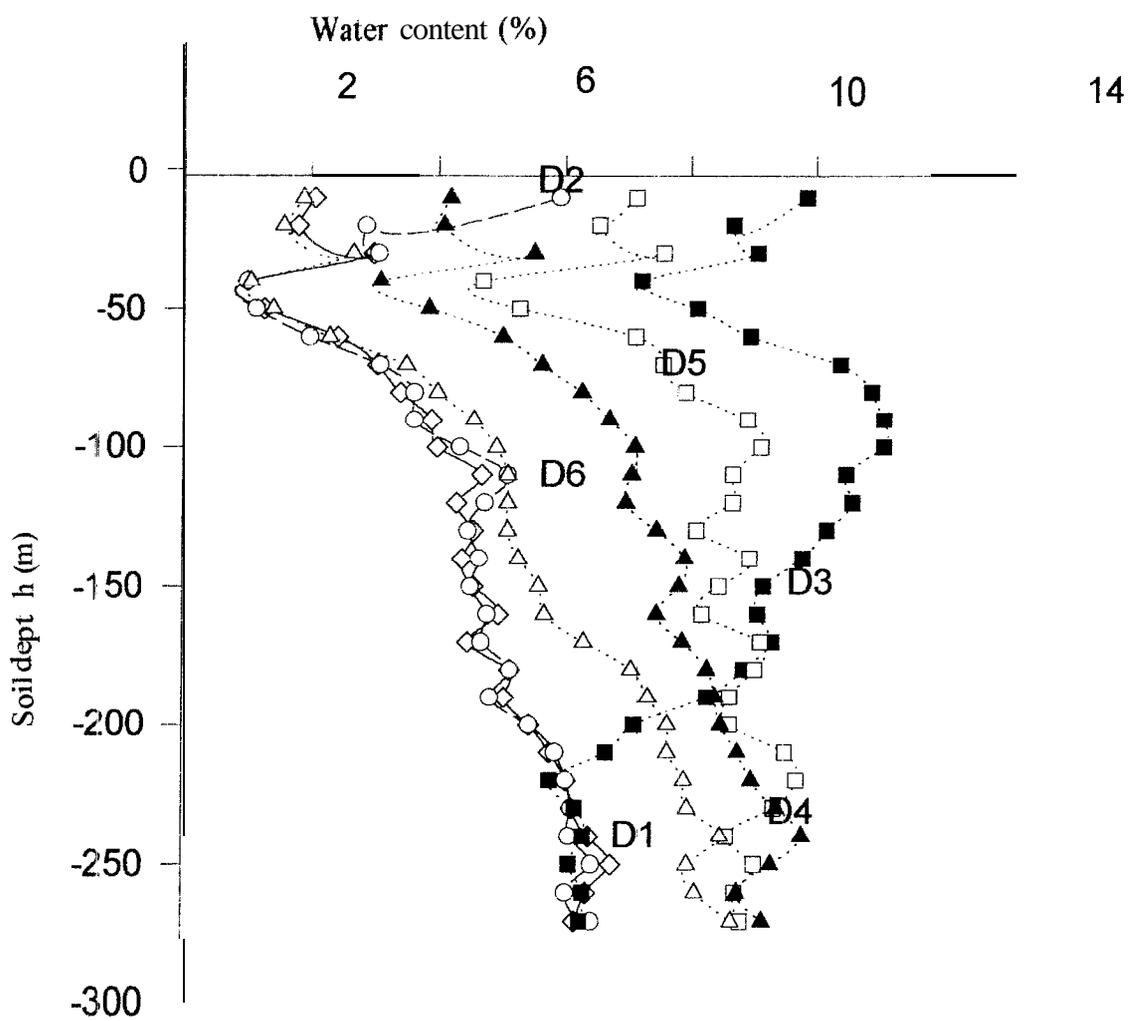


Figure 3b: Change in soil water content in the profile

Treatment : Manure + (PG + RP) mix

First of all, regardless of the treatment, the water content values are well below the water saturation for this type of soil (Cissé, 1990; Sène, 1995). This could mean that water infiltrated in the soil is being used as long as the rains are falling.

Secondly, the wetting front has gone deep in the soil profile (below 2 m), so that water drainage has occurred. Soil water balance requires then an estimation of the drained water.

b. On-farm experiments

On-Farm Experiment in the Corn/Peanut Cropping System near Nioro Station

Yields components are shown in Table 6. The plant population lower than that mentioned above for the on-station experiment is common in farm cropping situation. The ANOVA performed shows no significant treatment effects on peanut yield components.

Table 7: Peanut Yield for on-farm Experiment near Nioro. 1998

Treatment	Plant population	Pod + Hay	Hay	Pod
T1	70620	2430	1380	1050
T2	74270	2290	1260	1040
T3	61930	1830	1080	750
T4	71405	2430	1340	1090
T5	71400	2260	1310	950
Mean	69930	2240	1270	974
Sign. Level	NS	NS	NS	NS
CV (%)	8.8	19.3	20.3	22.3

No major water stress has occurred during the rainy season, due to the good rainfall distribution. In this degraded soil fertility situation of the continuously cropped field (Diack et al, 1998), the lack of direct effect of P amendment application on peanut could indicate that nutrients added are not readily available for crop. As for the manure application, the lack of direct effect confirms research findings indicating that peanut respond better to residual effect.

On-Fax-m Experiment at Ouadiour for the Peanut/Millet Cropping System

The effect of PG and RP mix and/or manure on yields for the peanut/millet cropping system is shown (Table 7). Despite the fairly good plant population obtained, the yield components namely hay and peg yields are low. There is no significant effect of the treatments. From the water balance measurements (data not shown), a very deep water percolation is observed. This indicates a low water use efficiency which also occurs in the sandy soil.

Table 7: Peanut Yield for on-farm Experiment at Ouadiour.

Treatment	Plant population	Pod + Hay	Hay	Pod
T1	87590	1130	740	370
T2	88420	1240	800	470
T3	86080	1080	710	390
T4	94080	1140	750	390
T5	87690	1130	740	390
Mean	88990	1140	750	380
Sign. Level	NS	NS	NS	NS
C V (%)	5,7	8,4	9,1	11,2

On-farm Experiment at Koutango for the Continuous **Rice Cropping System** in the Valley Bottom.

The **yield** components obtained using an upland rice variety are shown in Table 8. The ANOVA shows no **significant effect** of the treatments. The paddy yields values with a **mean of about 5 tons/ha** show a real rice production potential in the valley.

The soil water profile monitoring **indicates** a fairly good water availability to crop, (data not shown). The water table **during** the cropping season has remained shallow (< 1 m) (data not shown). Therefore, chances are that the **groundwater** through capillary rise participates in plant water uptake when a drought period occurs.

Table 8: Effect of Treatments on Rice Yield (var. DJ-684D) at Koutango. 1998

Treatment	Plant population	Paddy	Stalk	Panicle	WT of 100 gr
T1	325000	4663	4989	5264	2.32
T2	316666	4692	5320	5254	2.35
T3	350625	4102	4267	4616	2.35
T4	304375	4440	5083	4983	2.4
l-5	32479 1	4006	4286	4481	2.3
Mean	324292	4381	4789	4920	2.34
Sign. Level	NS	NS	NS	NS	NS
c v (%)	12.5	18.1	14,9	18.1	4.8

4. Conclusion

Long ter-m experiments were **installed** in **three different** cropping systems in the **peanut basin** to address the sustainability of the food production increase, by **means** of the enhancement of soil fertility. It is assumed that the **key factor** there is the optimization of water and **nutrient** use. The **results** obtained **from** the **first** year of implementation must be considered as the basis for a necessary continuation of the work **underway**. For the **next** cropping season, **focus** will be put on the determination of the **different** components of water and **nutrient** balance.. **Soil** water percolation (drainage) for upland. cropping systems and upward water flow in the **rice** root zone in the lowland system must be determined as accurately as possible. This poses the problem of required equipment. The **additional** needs in that regard concern the tensiometers for soil water pressure monitoring.

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THEME 3 : NUTRIENT MANAGEMENT

Effect of organic and inorganic fertilizers on the nutrient status and yield of dryland crops

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Abstract

Capeverdean subsistence farmers cannot afford to **invest** in expensive **fertilizers** to supply nutrients to their **dryland** crops; therefore, application of animal **manure** alone or **mixed** with **moderate** amounts of **chemical fertilizers** could be a possible alternative. Animal manure, besides being **valuable** sources of nutrients, **increas** water and **cations** retention of the soil and, when applied alone or in combination with **moderate** amounts of chemical fertilizers, **increase** yields of crops and available **nutrient** content of **soils**. This field work was conducted at the Ribeira Seca watershed to determine the **effect** of animal manure and NPK fertilizer in the yield **and growth** of **dryland** crops, **in particular**, **corn** (*Zea mays*) and beans (*Vigna unguiculata* and *Lablab niger*). The experiment was set **up** in a randomized **complete block** design **with four** replication in **which** the treatments were: 1. **Control**, with no chemical or organic fertilizers; 2. 60 kg **N/ha** in which 50% was applied **preplant** as NPK (16-10-20) and 50% as ammonium sulfate (50% N) as sidedress, four weeks **after** planting; 3. **20 t/ha** of **cow manure incorporated into** the soil; and 4. **combination** of treatments 2 and 3. **Since** it did **not rain enough**, the crops did not **reach maturity**. The parameters **evaluated** were: com **plant** height, com **dry matter** yield, **nutrient** content of **bean plant tissue**, bean grain yield and **soil nutrient** content. **Treatments** did not affect com plant height, soil **nutrient** content or bean grain yield. The application of NPK and manure, alone or **combined** with **each other increased** corn **dry matter** yield. The highest **dry matter** yield (3.92 **Mg/ha**) was **obtained with** the combination treatment, and the **lowest** (2.27 **Mg/ha**) with the **control**. Although there **were** some **inconsistencies**, the **study** suggests a **beneficial effect** of manure **combined with** NPK chemical **fertilizer**.

1. Introduction

In Cape Verde, **dryland** crops, mainly **corn and beans**, are **grown** under poor management **with** no chemical or organic fertilizers as **nutrient** sources. **Since** Capeverdean subsistence farmers cannot afford to invest in expensive fertilizers to **supply** nutrients to their **dryland** crops, **application** of animal manure alone or **mixed** with **moderate** amounts of chemical fertilizers could be a possible alternative.

Animal manure, besides being **valuable** sources of nutrients, **increases** water and cations retention and, when applied alone or in combination **with** chemical fertilizers, **increases** yields of crops **and** available **nutrient** content of **soils**. **Organic nutrient** sources **such** as animal manure **may** reduce the **amount** of fertilizers required for optimum com **growth** and **yield**. However, the amount of animal manure is **limited** and **farmers usually do not** have enough to **apply** on the slopes where **dryland** agriculture is practiced. On the other **hand**, the animal manure used is **generally** low in **nutrient** content, **particularly** N, **because** of the animal **diet and handling** of the manure **during** collection, storage and application.

The objectives of this field **trial** were:

1. To **extend** the animal manure both chemically, **biologically** and physically

by **combining** a **moderate** amount of NPK fertilizer with the manure and applying it to **dryland soils** where com and beans are **grown**;

- 2. To **evaluate** the effect of both chemical **fertilizer** and animal manure on **crop** growth and yield.

2. **Materials and methods**

This field experiment was conducted at a **farmer's** field near S. Jorge, in the Ribeira **Seca** watershed **during** the 1998 growing season. The **soil** at the experimental site was a loam and laboratory analysis **showed** that initial **soil** pH was 6.8, OM content 1.04% (dry combustion), **P₂O₅** (Olsen) and **K₂O** (ammonium acetate) in the top 20 cm were 109 (**very high**) and 636 (**very high**) ppm, respectively. **Nitrogen** content was extremely low. The cow manure used **contained** 1.1% N (Kjeldahl digestion); 0.8% P (colorimetry); 1.5% K (flame photometry); 19% **OM** (dry combustion) and 26.2% moisture.

The experimental design was a randomized **complete block** with four treatments replicated four times. Experimental units were plots with 28 m². The treatments were:

- 1- Control, with no chemical or organic fertilizers;
- 2 - 60 kg **N/ha** in which 50% was applied preplant as NPK (16- 10-20) and 50% as **ammonium sulfate** (50% N) as sidedress, four weeks **after planting**;
- 3 - 20 **t/ha** of cow manure incorporated into the **soil** with a hoe before seeding;
- 4 - and a combination of treatments 2 and 3.

Com and beans were sown on July 27 (**after** what **later** proved to be an **insignificant rainfall**) in hills at rate of 28 hills per plot and four maize seeds and 2 different bean seeds per hill. Com seeds used were of a local variety and the beans were cowpea (*Vigna unguiculata*) and feijão pedra (*Lablab niger*).

Com plant height was **measured from** soil level to tip of first **fully** developed leaf, two months **after** seeding, by randomly selected 6 plants in **each** plot. Bean tissue samples (**young** fully developed leaves) were **collected from** 20 randomly selected plants in **each** plot for analysis of dry **matter** N, P and K concentrations. Total N, P and K were determined by Kjeldahl analysis, colorimetry, and flame photometry, respectively. Com ear leaf samples were **also** supposed to be **collected** for dry **matter nutrient** analysis but, at that time, the **crop** was already **suffering from** moisture stress.

There was no harvest of grain yield because **lack** of rain prevented the **crop from** reaching **maturity**. *Only* the *Vigna unguiculata* produced some grains, which were harvested on November 10. Both grains and pods were weighed. To compensate for the **lack** of com grain yield, the straw in **each** plot was cut at **soil level** and **weighed** to determine the effect of treatments on dry **matter** yield. The straw was not completely dry at cutting time; therefore, moisture content was determined by drying straw samples at 65 °C for 48 hours. Plant population was **also** determined because it was not uniform for all plots. Soil samples were **collected** at 20 cm depth in **each** plot at the end of the experiment for **laboratory** analysis of pH (1:2 **soil:water**); N (**Kjeldahl**); **P₂O₅** (Olsen), **K₂O** (ammonium acetate) and OM (dry combustion).

Data were **analyzed** using analysis of **variance** and covariance. Fisher's LSD test and multiple range analysis were employed to separate treatment means.

3. Results and Discussion

Table 1 shows the rainfall amount and distribution **during** the period of the experiment. **It can be seen** that the rains started **very late** in the season **and** ended **very early**. In **fact**, the **first** significant **rainfall** only fell in **late** August and the **last** at the end of September. **Rainfall** was **insufficient** and poorly distributed **during** the trial period which **caused** the **crops** to **fail**. Soil moisture was **insufficient** at seeding time, causing poor **emergence** and early growth of both **corn** and beans, even though seeding was **done** twice. **After** tasseling it did not **rain** anymore; therefore, there was not enough soil moisture to **promote** grain filling and, consequently, there was no grain yield.

The analysis of **variance** and **covariance** (Table 2) indicated a highly significant **effect** ($p < 0.01$) of the treatments on **corn** dry **matter** yield (52% moisture). The use of the number of plants as covariate **turned out** to be **very significant** ($p < 0.01$) in **reducing** the **experimental** error and detecting real **differences** due to treatments. A more detailed analysis showed that NPK fertilizer and manure increased **corn** dry **matter** yield both when applied separately and in combination with **each** other. However, a positive interaction between NPK **fertilizer** and animal manure was not verified. **It is** important to keep in **mind** that this soil was high in P and **K and**, therefore the results in this situation of high **P&K** fertility no positive interaction occurred.

Table 3 shows the **effect** of treatments on **mean** dry **matter** yield and height of **corn** plants. The **mean** dry **matter** yield of the NPK treatment was not **significantly different from** that of the animal manure treatment. The combination of the chemical **fertilizer** and the manure resulted in an **increase** of 42 and 23% **over** the control and **the** manure alone, respectively. Dry **matter** yield appears to be additive between application of NPK and animal **manure**. There was no significant **difference** between the combination **and** the NPK **fertilizer** alone. **Mean** dry **matter** yield was higher for the NPK treatment than the manure treatment. Multiple range analysis showed a **mean** **corn** dry **matter** yield of 2.4 and 4.0 **Mg/ha** for without **and** with NPK fertilizer, respectively, while for the without **and** with **manure** treatment **it** was 3.0 and 3.4 **Mg/ha**, respectively. Given the high soil P & K **one is left** to speculate that the yield improvement might be due to N. **It could** be interesting to calculate the N contribution **from** manure in **comparison** with that in the NPK fertilizers perhaps foliar N levels would help test this hypothesis of the N **effect**.

In spite of the positive **effect** of the treatments on dry **matter** yield, the treatments did not have **any** significant **effect** on early **corn** plant height. In the **same** way, the treatments did not have a significant **effect** on bean grain yield (Table 3). Bean grain yield was **very** low, with a **mean** yield of 22 **kg/ha** due to **lack** of rain after flowering, causing poor grain filling. Grains were also **very** small.

Soil analysis at the end of the growing **season** did not indicate a **significant** **effect** of the treatments on soil N, P and **K** content (data not shown). This **could** be due to the **very** high initial P_2O_5 and K_2O content of the soil. **In fact**, according to INIDA's soils **laboratory** **recommendation**, a response to application of P and K **should** not be expected in **such** condition. However, the application of **manure** resulted in a highly significant ($p < 0.01$) increase in soil organic **matter** content (Table 4). But, in spite of the increase, the organic **matter** level is still in the low range for all treatments ($< 2\%$). This **could** be due to the low OM content of the manure applied to the soil and also because a large amount of OM is required to **build** up in the soil.

With the application of manure and NPK **fertilizer** the **nutrient** concentration in the bean plant tissue increased **significantly** (Table 4). However, according to INIDA's

soil fertility and **crop fertilization manual (1997)**, in spite of the **increase**, the concentration of N and P in the bean plants are **still** below **sufficiency** range. The low **nutrient** concentration in the tissue samples could be due to water stress which limited **nutrient** uptake. The combination of NPK **fertilizer** with **animal** manure resulted in the highest tissue concentration of N, P and K which **means** that the **combination** promoted more **nutrient** uptake than the individual application of NPK or **manure**.

4. Conclusion

It is obvious that the experiment did not **give** the expected **results** because of the delay, **poor** distribution and **shortage** of **rain**. **Dryland** experiments in Cape Verde are **always risky** because of the **uncertainty** of the **rains**. With this **trial** we could not **evaluate** the effect of the treatments on **corn** grain yield as expected, but we tried to **evaluate** treatment **effects** on other parameters **such** as corn plant height, **soil nutrient** content, corn **dry matter** yield and concentration of nutrients on bean plant tissue.

The results suggested that, although the application of the manure **alone** increased corn dry **matter** yield **significantly**, the combination with manure is more **desirable** because of the effect on **nutrient** uptake and other **soil properties**. However, the **trial should** be repeated in favorable **soil moisture** condition to reach the **conceived** objectives and to consolidate the **results** of this study.

Table 1. Growing season rainfall data (cm) at S. Jorge, 1998

Dates	Months				
	July	August	September	October	November
1	0	0	0	0.1	0
2	0	0	0.2	0.3	0
3	0	0	0.1	0.3	0
4	0	0.3	0	0.1	0.1
5	0	0	0	0.2	0.2
6	0	0	0	0.1	0.1
7	0	0	1.3	0.1	0
8	0	0	0	0	0
9	0	0	3.1	0	0
10	0	0	9.2	0.5	0.1
11	0	0.2	17.7	0.2	0
12	0	10	36.7	0.7	0
13	0	0	0.1	0.1	0
14	0	0.2	0	0.1	0
15	0	0	0	0	0
16	0	2.1	16.5	0	0
17	0	0	16.8	0.1	0
18	0.2	0	25.2	0	0
19	0	0	2.2	0	0
20	0	0	0	0	0
21	0	2.4	0	0	0
22	0	40.2	15	0.2	0
23	0	0	0.1	0.1	0
24	8.5	0	0	0	0
25	5.5	0	0	0	0
26	0	0	0	0	0
27	0	10.5	1	0.2	0
28	0.2	11	32.6	0	0
29	0.8	0	7.5	0	0
30	1.6	0	0.1	0.1	0
31	0.4	0	0	0	0
total	17.2	76.9	183.4	3.5	0.5

Table 2. Analysis of variance and covariance relative to the effect of treatments on corn dry matter yield

Source of variation	d.f.	SS	MS	F	sig. level
Plant #	1	13.982	13.982	11.02	**
Blocks	3	9.406	3.135	2.47	NS
Treatments	3	41.378	13.793	10.87	**
NPK	1	30.768	30.768	205.63	**
Manure	1	9.572	9.572	63.97	*
NPK * Manure	1	0.629	0.629	4.20	NS
Error	8	10.153	1.269		
Total	15	74.920			

* - $p < 0.05$; ** - $p < 0.01$; NS. - not significant

Table 3. Effect of treatments on corn plant height, corn dry matter yield and bean grain yield

Treatments	Corn plant height (cm)	Corn dry matter yield		Bean grain yield	
		kg/28 m ²	Mg/ha	kg/28 m ²	kg/ha
Control	1.24	6.37	2.27	0.052	18.58
NPK fertilizer	1.26	9.86	3.52	0.064	22.86
Manure	1.32	8.50	3.11	0.063	22.50
NPK + manure	1.32	10.97	3.92	0.070	25.00
LSD (0.05)	0.15	1.83	0.65	0.029	10.26

Table 4. Effect of treatments on bean plant nutrient concentration and soil OM content

Treatments	N %	P %	K %	Soil OM content %
Control	3.50	0.26	2.07	1.07
NPK fertilizer	3.83	0.28	2.23	1.23
Manure	3.80	0.29	2.28	1.73
Manure + NPK	3.83	0.30	2.50	1.85
LSD (0.05)	0.19	0.01	0.16	0.26

An Integrated Fertilization Study of the Groundnut-Millet Rotation Cropping System.

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Abstract

Like elsewhere in the Sahel, agriculture is the most important economic sector in The Gambia. This sector **provides** employment for more than 75% of the rural population, contributes between 20-25% to the **country's** Gross Domestic Product (GDP) and generates **almost** 85% of **foreign exchange** earning and 40 % of total export **earnings**. This agriculture is, however, at a crossroad with **declining** per capita production and a deteriorating resource base. The region most **affected** is the North Bank **Division** of **The** Gambia. The **North bank** division is **one the most** important agricultural **regions** in **The** Gambia. This region covers an **area** of 221, 000 ha, has a population of 156,000 people (15% of national population), and a total of 45,000 cattle, 64,000 small ruminants, 11,000 **horses** and donkeys (draft animals). These **resources** put together **account** for 33% of the total **agricultural** output of The Gambia.

Currently, this region is experiencing a steady loss in **crop** production **capacity**, which is on the **one** hand on **account** of the weather (low **rainfall**), but most **often**, a limitation posed by low soil fertility. Low **crop** yields in this region are due to the **combined** effects of low **inherent** soil fertility and agricultural expansion **characterized** by resource based (**natural soil fertility**) farming systems.

Resource-poor **farmers**, further constrained by **removal** of subsidies, often **cannot** apply recommended fertilizer rates, **hence** have sharply reduced **fertilizer** use. **Fertilizer** use in The Gambia dropped to less than 5 **kg/ha** in 1996 **from** the application rate of 16 **kg/ha** in 1985. These **farming** systems are **nutrient mining**, resulting in the **negative nutrient flows** and **nutrient** balances. Resource-based farming is **unsustainable** and **often** goes hand-in-hand with land degradation.

Reduced dependence on chemical inputs and increased dependence on **available** local **resources** is most appropriate for a fragile and stressed ecosystem under the management of a resource-poor **farming community**. For environmental degradation to be reduced and the production performance of the **existing** croplands increased, there is the need to improve the **nutrient** budgets of these soils through organic or inorganic sources. However, socioeconomic conditions, availability of inputs and **limited** soil **resilience** favor the integration of the two strategies.

The study (in a **randomized complete block** design with four replications) utilized a groundnut-millet rotation system to assess: i) the long-term changes in soil chemical properties due to **soil** amendments and ii) the long-term **effect** on the production of the rotation system. The interaction effects of **different** manure (**stable** and **cow dung**) at 3 t/ha with five levels (0, 15, 30, 35 and 40 **kg/ha**) P_2O_5 or N were evaluated for groundnut and millet respectively at Njaba Kunda.

Two-year results showed that manure + fertilizer was superior to fertilizer applied alone especially at low rates on **crop** biological and economic yields. The

integrated fertilization strategy increased the output of the rotation system by **over twice** the **control** (no fertilization) and **7%** more than **fertilizer applied alone**. This **complementary effect** of manure and fertilizer was **manifested across** rates and a sure strategy for **increasing fertilizer use efficiency**.

In addition, the **combined** (integrated) **fertilization** strategy impacted on physical and physiochemical properties of the nutrient-poor and **poor-buffering** soil of Njaba **Kunda**. The loss in **soil** productivity is **often** related to loss in soil organic **matter**. Soil organic **matter** the key **attribute** of soil **fertility** was enhanced **significantly over mineral fertilizer alone**. The **increase** in soil organic **matter** in manure and manure + **fertilizer applied** plots was due to the **reduction** in the rate of soil organic **matter loss**. The manure treatment **acted** as a strong **check** against decomposition. **Also**, bases **such** as calcium and potassium were enhanced that **can bring about increased** plant nutrition **and** reduced acidification.

From the indications of this **experiment**, under **current** farmers' practice there is the threat of **decline** in productivity **overtime** with the likelihood of irreversible environmental degradation. Therefore, in order to **maintain** productivity, there is the need to adopt the use of **soil** amendment particularly **from** organic sources.

Such an **experiment** needs to be long-term in order **identify** key **indicators** of land degradation as **soil** organic **matter** and **establish critical** values for them for **different** agroecologies. Also, in order to **facilitate** large-scale manure use especially on faraway fields, there is the need to look **into** 'more **efficient** manure **transportation means** and proper field storage methods.

1. Introduction

The maintenance of **soil fertility**, given an **increasing intensity** of land use associated with population growth **and mechanization**, is crucial to the long-run productivity of **Gambian** farming systems. Yields of **crops**, particularly food **crops**, are **either declining** or stagnant **and** the demand for **food** is **increasing** more **rapidly than** at anytime in **history**. The steady loss in **crop production capacity** in The Gambia is on the **one** hand due to **recent** years of low **rainfall**, but most significantly, is a limitation posed by low **soil fertility**.

Resource-poor farmers, further **constrained** by the **removal** of **subsidies** on **fertilizers**, **often cannot** afford to apply the recommended fertilizer rates, **hence they have** reduced fertilizer use. **Fertilizer** use declined **from** an **already low** of 16 kg/ha in the mid-1980s to **less than** 5 kg/ha N-P₂O₅-K₂O in 1996 (FAO, 1996). According to Rhodes et. al. (1996), The **Gambia** is a **moderately nutrient deficient** country with a negative **nutrient flow** of 14-3- 16 kg/ha (N-P₂O₅-K₂O). These farming systems are **nutrient mining**, since output exceeds input, resulting in a net negative nutrient flow.

Farmers' **reaction** to the decreasing yield situation is to increase the planted area more by **using** more marginal **lands**. No **where** is the problem is more **evident** than in the North **Bank Division** (NBD), a region **being** among the most important in the **country** agriculturally.

The **NBD** covers an **area** of **about** 221,000 ha, of which 42% is **suitable** for agriculture and another 21% is considered marginal. **Cropland** covers **slightly** more than 45% of the **area**, with **vegetation cover** of **less than** 10% of the **landscape** (Dunsmore et al., 1976). It has a population of 156,000 people (15% of the national population), a total of 45,000 cattle, 64,000 **small** ruminants, 11,000 **horses** and

donkeys (Population and livestock census, 1993). These resources put together account for 33% of total agricultural output of The Gambia.

The cropping systems on the uplands are largely a groundnut-cereal (early millet) rotation. The North Bank has the largest area of groundnut in the country, varying between 20,000 and 30,000 ha, with an average yield of little more than 1 ton/ha. The early millet area has been growing rapidly and yields average about 900 kg/ha (Posner et al., 1989).

Most farmers have for a long time known the use and importance of both manure and inorganic fertilizer in increasing crop yields through soil fertility enhancement. The use of manure is the major soil fertility maintenance strategy in the inner fields (close to compounds), on food crops. The effect of fertilizer, on the other hand, has been demonstrated to these farmers on all major crops and adoption rates have been high for cash crop until subsidies were removed on fertilizer and it became unaffordable to the majority of these resource-poor farmers.

Manure can offer multiple benefits, but it is not available in the quantities required. Exclusive dependence on chemical fertilizers on the other hand even where affordable, may have detrimental effect on the long-term productivity of the natural resource base. Reduction of dependence on chemical inputs and increased dependence on available local resources such as manure, compost and crop residues would be the most appropriate technology for a fragile and stressed ecosystem under the management of a resource-poor farming community.

This therefore, calls for an integrated plant nutrient system approach. The main goal of this strategy will be to integrate the use of organic and inorganic sources of plant nutrients for a sustainable increase in agricultural productivity in an efficient and environmentally friendly manner.

Specific hypotheses

1. Stable manure is of higher quality in plant nutrient content and organic matter and of more value than cow manure in improving crop response to applied fertilizer.
2. Soils in the study area (Njaba Kunda) are nutrient-deficit (negative flow) and are likely respond to soil amendments and improvements in the nutrient budget.

Specific objectives

- i) to assess the changes in crop responses (yields) to different soil amendment materials.
- ii) to assess changes in soil properties due to the effect of different soil amendment materials.

2. Materials and Methods

Experimental site

This two-year (1997 and 1998) experiment was conducted on an upland site in Njaba Kunda in the central region of NBD, taking into consideration the dominant cropping systems (groundnut-millet rotation system). Njaba Kunda is in the Sudano-sahalian agroclimatic zone with a mean rainfall of 700 mm. The seasonal rainfall at the site were 648 and 805 mm, being 93 and 115% normal, for the first and second year respectively. The first cycle of the experiment (1997) with groundnut, was replicated at three sites other than Niaka Kunda, which differed in soil and annual mean rainfall: Yundum (soil association 1); Jenoi (soil association 2); and Sapu (soil association 6). Rainfall for these sites in 1997 was; 900, 651 and 865 mm respectively.

Soils

Generally, the soils of the uplands belong to the soil order of Alfisols, with low fertility for reasons of geology and human activity. Soil associations 1 and 2 have similar

characteristics; they are deep, **well-drained**, moderately permeable soils of the uplands with loamy sand or **sandy loam surface** layers and a **sandy clay loam subsurface**. However, soil association 2 (at the point of Njaba Kunda) has an eolian deposited parent material, hence coarser in texture because of lower silt + clay (< 10%) content (Dunsmore et. al., 1976).

Association 6 soils on the other hand are deep, somewhat poorly drained and moderately slowly permeable. For both years, preplant and postharvest soil samples were collected at a depth of 0-20 cm, air dried and ground to pass a 2 mm-sieve. Measurements were made on soil pH (water and KCl) in a soil to water/solution ratio of 1:2.5 using a glass electrode. Organic matter content was determined using the loss-on-ignition method. Total N was determined by micro-Kjeldahl method and macrocations (Ca, Mg, and Na) determined by flame photometry and available P was determined by the colorimetric method using the spectrometer 21.

Field experiment

A randomized complete block experimental design was employed to evaluate the integrated fertilization effect of organic (manure) and inorganic (fertilizer) sources of plant nutrients on crop yields and soil chemical properties in a groundnut-millet rotation cropping system. Three types of soil amendments (no manure, stable manure and cow dung) were applied at a rate of 3 tons/ha, in four replications, and were evaluated under five levels (0, 15, 30, 45, and 60 kg) of applied fertilizer.

Planting was done on flat land (no tillage), but mechanized for both crops (groundnuts and millet) using animal traction. The groundnut variety 73-33 was planted at a spacing of 50 cm x 12 cm and the millet variety (local) was planted at a spacing of 75 cm x 75 cm, inter-row vs intra-row. For both crops the experimental unit was 15 m².

Phosphorus fertilizer was applied to the groundnut crop at the specified rates as triple superphosphate. In the second year, nitrogen in the form 15-1 5- 15 and urea was applied to the millet crop. For groundnut, both the manure and the phosphorus fertilizer were applied and incorporated at time of planting. For millet crop, manure was basally applied and incorporated while N was applied in two splits, two-third the amount (2/3) at 3 weeks after planting and one-third (1/3) at 6 weeks after planting.

For each year, data on stand count at harvest, dry pod yield and biomass were collected. The data were statistically analyzed using the MSTAT and Minitab software packages.

3. Results and Discussions

Groundnut crop-year 1

Table 1 presents mean groundnut pod yield data of the 1997 experiment across the four locations evaluated (Yundum, Njaba Kunda, Jenoi and Sapu). Yields of groundnut pod weight ranged from a low of 700 kg/ha to a high of 2000 kg/ha in Yundum. Differences in mean pod yield among locations may in part be due to variation in seasonal rainfall and soil environment. Yundum and Sapu have comparatively more moisture (940 and 856 mm of rainfall compared to 648 and 651 for Njaba Kunda and Jenoi), Heavier soils (> 15% silt + clay) at Yundum and Sapu than at Njaba Kunda and Jenoi (< 10% silt + clay). Jenoi and Sapu also had lower plant populations due to 2 1-day dry spell following planting and due to erosion respectively.

Analysis of variance on individual sites (annex) indicated that there was a differential response to soil amendments across locations. Yundum had significant manure x fertilizer interaction effect, while Njaba Kunda and Jenoi indicated significant main effects in added fertilizer and Sapu showed no treatment effect.

Combined analysis was only possible for Yundum and Njaba Kunda and suggested significant interactions among manure + fertilizer treatments. Table 3 shows higher mean yields for manure + fertilizer, particularly with stable manure, than for fertilizer added alone. Stable manure gave the highest yield at 15 kg P₂O₅/ha but still produced higher yields at each corresponding fertilizer level than cow dung or fertilizer alone. Cow dung, however, produced higher mean yields than fertilizer alone and showed a negatively linear response with incremental rates of phosphorus fertilizer.

Average fertilizer effect (Table 4) was higher in Njaba Kunda than at Yundum with an mean average increase in yield of 896 and 394 kg/ha or 75 and 26% more than their control, respectively. The application of 3 t/ha of stable manure or cow dung produced an average yield difference of 410 and 960 kg/ha, respectively over the control. Average performance of stable manure + fertilizer and cow dung + fertilizer were comparable, with 50 and 52% yield increase respectively over the control mean yield.

The better groundnut response to fertilizer at Njaba Kunda may be attributed to the lower fertility level of Njaba Kunda soils, thus increasing the likelihood of response. When Njaba Kunda was analyzed separately the only significant difference was between soil amendment against no soil amendment. Even though non-significant, yields were higher with manure plus fertilizer than for fertilizer alone, at the corresponding level of applied fertilizers. The yield advantage of the manure + fertilizer plot was most likely due to the additional nutrients and soil moisture enhancement provided by the manure to this nutrient-poor and low-water retaining soil.

Table 1: Mean Pod yield (kg/ha) of Groundnut across Locations as Affected by Soil Amendment in 1997.

Manure	P ₂ O ₅ -Level	Yundum	Njaba	Jenoî	Sapu	Mean
@ 3 t/ha	kg/ha	Kunda				
Nomanure	0	1514	1192	510	1125	1085
“	15	1799	2133	608	1285	1455
“	30	1847	2025	745	1344	1490
“	45	2076	2026	845	1177	1541
“	60	1910	2125	608	1750	1598
Stable manure	0	1875	1650	700	1396	1405
“	15	2118	2333	777	1281	1627
“	30	2070	2000	883	1583	1634
“	45	1882	1708	790	1396	1444
“	60	2069	2033	608	1365	1519
Cow dung	0	2792	1833	753	1302	1670
“	15	2333	2200	567	1167	1567
“	30	1910	1917	748	1271	1461
“	45	1972	2042	770	1052	1459
“	60	1958	2075	708	1177	1480
Location mean		2008	1956	708	1311	

1. Manure; 1 = No manure, 2 = Stable manure, 3 = Cow dung

2. P-Level; 1 = 0, 2 = 15, 3 = 30, 4 = 45, 5 = 60 kg P₂O₅

Table 2: Mean pod yield (kg/ha) from manure x fertilizer interaction averaged over Yundum and Njaba Kunda

Added kg/ha P ₂ O ₅ (fertilizer)	No manure	Stable manure	Cow dung
0	1353	1763	2313
15	1966	2222	2267
30	1936	2035	1913
45	2072	1795	2007
60	2017	2035	2017

Regression Equations

1. Fertilizer: $Y = 1415 + 31.8 P - 0.371 P^2$, $r = 0.948$ $X_m = 43$ kgP₂O₅/ha
2. Stable Manure $Y = 1877 + 9.74 P - 0.146 P^2$, $r = 0.342$ $X_m = 33$ kgP₂O₅/ha
3. Cow dung $Y = 2353 - 16.3 P - 0.178 P^2$, $r = 0.876$ $X_m = 45$ kgP₂O₅/ha

X_m = Amount of fertilizer nutrient required for maximum yield.

Table 3: Average site-specific performance in groundnut pod yield as affected by the different soil amendments.

	Yundum	% increases in yield	Njaba Kunda	% increases in yield
Fertilizer	1908	26	2088	75
Stable manure	1875	24	1650	38
Cow dung	2791	84	1833	54
Stable + fert.	2035	34	2019	69
Cow dung + fert.	2043	35	2058	73
Control	1514		1192	

In order to answer some meaningful practical questions, preplanned comparisons were performed. Orthogonal contrasts (Table 5) on groundnut pod yield from Njaba Kunda revealed that the only significant comparison was between amendment and no amendment. The application of soil amendments whether fertilizer, manure or the combination of the two significantly increased yield over no application of soil amendment. This indicated that the natural soil fertility at the site was low, hence it could not provide adequate plant nourishment and, therefore, requires supplementation.

From the fitted orthogonal polynomials (Table 6), responses in pod yield to the different amendments were curvilinear, an indication that the change in pod yield was not constant for every incremental change in applied soil amendment. The response to

fertilizer applied alone was quadratic, cubic for stable manure + fertilizer and not defined for cow dung + fertilizer. According to the fertilizer response function, groundnut pod yield will increase by 43-kg pod/kg of P_2O_5 applied as fertilizer alone and maximum yield was obtained at 41 kg P_2O_5 /ha.

For stable manure + fertilizer, the change in pod yield at low rates was 84 kg pod/kg P_2O_5 . However, yield declined faster than the decrease in fertilizer at intermediate rates (> 30 kg/ha), but peaked up again at higher rates. Especially noticeable on tropical sites was the effect of manure as a P fertilizer and the improved effectiveness of mineral P fertilizers when combined with manure. Initial available P in these soils was low (<10 ppm), and are largely stored in the soil organic matter which is readily depleted. Fertilizing with manure can counteract P deficiency or its reduced availability on cultivated soils. How manure brings about an increase in available P may be chemical, physical or biological in nature :

- 1) organic colloids prevent dissolved phosphate from coming into contact with free aluminum and iron,
- 2) when organic matter decays, the organic acid that forms dissolves phosphate,
- 3) organic phosphorus is less strongly fixed by soil and
- 4) microorganisms mineralize organic phosphate compounds.

Millet crop-year 2

Mean grain yield of 557 kg is below the average yield in the area (Table 5) and was attributable to late planting and disease infestation (Downy mildew). Farmers in this area 'dry seed' their early millet in order to gain time for planting groundnuts whereas, the experiment was planted when the soil was sufficiently soaked by rains. Grain yield ranged from a high of 866 kg/ha for cow dung + 60 kg N/ha to a low 125 kg/ha for the control (no fertilization).

Grain yield was affected also by Downy mildew infestation, especially in the low fertility plots. The effect of the disease on grain yield was manifested through depression of plant vigor affecting parameters such as tiller production for panicle count and plant height. Plots with disease scores of 7 and 9 (high infestation) had significantly fewer panicles and shorter plants. The occurrence of heavy downy mildew disease infestation corresponding to low fertility plots was an indication of the importance of fertility in pest and disease management.

The main effects of the experiment (Table 5), manure and fertilizer, were significant for grain yield, panicle count and plant height with least significant differences at the 5% level of 135 kg/ha, 11 panicles and 11 centimeters respectively. Manure significantly outperformed no manure in all of the stated parameters. The average effects of manure on grain yield was 30% greater than that of no manure and among manure, cow dung produced the highest mean grain yield of 623 kg/ha. The response to fertilizer was cubic with extrema at 15 and 60-kg P_2O_5 /ha rates.

Orthogonal contrasts of treatment means (Table 5) revealed significant difference on millet grain yield in year two of the rotation experiment among the different soil amendments and also a manure x fertilizer interaction. In the first year of the rotation experiment with groundnuts, the only significant difference detected was between some soil amendment and no soil amendment on pod yield. Soil amendment was superior to no soil amendment and between the soil amendments, organic amendment combined with fertilizer was superior to inorganic amendment applied as fertilizer alone. Between the manure types, the interaction effect of cow dung + fertilizer was higher than stable + fertilizer.

The positive effect of manure on fertilizer use efficiency might be attributed to the delayed effects of manure. **After** repeated applications (**two**), both the immediate **effect** and the delayed effects of earlier applications **coincide**, and **manure** starts to have its maximum impact on yields. The **impact** of manure on yields **depends** strongly on the site that is, on **primary effect** on soils (as fertilizer, biological or physical) and on the state of the **soil**. The **soil** at the **experimental** site is both at nutrient-poor and **poor-buffering** capacity **status**. Therefore, the likely impact of manure is through **nutrient** supply and **enhanced** moisture retention and **availability** to the plant.

Table 4: **Effect** of **different** soil **amendments** on the grain yield, yield components and agronomic parameters of millet (year 2 rotation)

Treatment	Grain Yield kg/ha	Stand	Panicle count	Plant Ht count	Downy mildew (cm)				
Main effect									
<i>Manure</i>									
1	463 b	14	35b	139b	6				
2	583 ab	15	54 a	151 a	5				
3	623 a	15	47 a	151 a	6				
S_y	47	1	4	4	0.03				
Lsd .05	135	ns	11	11					
Fertilizer									
1.	414	c	14	35	b	135	b	9	
2.	606	ab	14	46	ab	154	ab	4	
3.	539	abc	15	44	b	139	b	6	
4.	522	bc	15	45	ab	152	ab	7	
5.	702	a	16	59	a	154a		6	
2	-----								
3	S_y	61	1	5	5				
4	Lsd	.05	174	ns	14	14			
5	-----								

Interaction effect

7	Manure	Fertilizer						
	1	1	125	d	13	10 d	114d	9
	1	2	642	abc	14	47 abc	154 abc	4
	1	3	467	bc	16	34cd	132 cd	6
	1	4		442bc	13	38bc	149 abc	7
	1	5	642	abc	17	49 abc	149 abc	6
	2	1	542	bc	16	51 abc	138 abc	6
	2	2		517bc	15	51 abc	154 abc	5
	2	3	542	bc	15	49 abc	148 abc	6
	2	4	717	ab	16	59 ab	160 ab	5
	2	5	600	abc	16	61 ab	154 abc	5
	3	1	575	abc	15	44 abc	154 abc	7
	3	2	658	abc	13	42 abc	155 abc	6
	3	3	608	abc	14	48 abc	137 bcd	7
	3	4	408	cd	17	38bc	149 abc	7
		5	866	a	15	66 a	161 a	4
Mean			557		15	46	147	6
S _y			106		1.5	9	8	
Lsd.05			302		ns	24	24	

Manure: 1=no manure, 2=Stable manure, 3=Cow dung.

Fertilizer: 1=0, 2=15, 3=30, 4=45, 5=60 kg N/ha

Table 5: Orthogonal Contrasts for 1997 Groundnuts and 1998 Millet Soil Amendment Treatments.

Contrast Prob.	Groundnut			Millet	
	DF	F value	Prob.	F value	
1. Amt. Vs Noue	1	12.68**	0.001	17.83	0.000**
2. Org. Vs Inorg.	1	<1		5.84	0.020*
3. F2 Vs SF2	1	1.30	0.260	<1	
4. F3 Vs SF3	1	<1		<1	
5. F4 Vs SF4	1	2.23	0.143	<1	
6. F5 Vs SF5	1	<1		1.06	0.309
7. F2 Vs CF2	1	<1		<1	
8. F3 Vs CF3	1	<1		<1	
9. F4 Vs CF4	1	1.337		<1	
10.F5 Vs CF5	1	<1		6.62	0.014**
11.SF2 V s CF2	1	1.30		<1	
12.SF3 Vs CF3	1	<1		<1	
13.SF4 Vs CF4	1	<1		6.29	0.016*
14.SF4 Vs CF5	1	<1		3.36	0.07

F2 = fertilizer at level2; SF2 = Stable manure + fertilizer at level2; CF2 = cow dung + fertilizer at level; Amt = amendment; Org. = organic; Inorg. = inorganic

Table 6: **Response Curves of Groundnut pod yield and Millet grain yield due to Different Soil Amendments.**

		Groundnut		Millet	
		SS	F value	SS	F value
DF					
<u>Fertilizer Effect 4</u>					
Linear	1	1294560.4	6.56*	277555.6	6.19*
Quadratic	1	747054.0	3.79*	66654.0	1.49 ns
Cubic	1	455395.6	2.31 ns	337824.7	7.54**
Deviation	1		<1		<1
<u>Stable manure Effect 4</u>					
Linear	1	17305.6	<1	39942.4	<1
Quadratic	1	106314.3	<1	390.3	<1
Cubic	1	898800.4	4.56*	46785.6	1.04 ns
Deviation	1		<1		<1
<u>Cow dung Effect</u>					
Linear	1	14745.6	<1	44622.4	<1
Quadratic	1	4536.0	<1	103544.0	2.31
Cubic	1	96432.4	<1	250905.6	5.60*
Deviation	1		<1		<1

Regression equations

Groundnut

Fertilizer: $Y = 1318 + 42.8X - 0.513 X^2$, $R^2 = 0.340$, $P = 0.03$

Stable manure: $Y = 1653 + 84.6 X - 3.52 X^2 + 0.004 X^3$, $R^2 = 0.383$, $P = 0.05$

Millet

Fertilizer : $Y = 136.0 + 58.6 X - 2.19 X^2 + 0.023 X^3$, $R^2 = 0.518$,
P=0.007

Cow dung $Y = 563.0 + 28.6X - 1.57 X^2 + 0.020 X^3$, $R^2 = 0.310$, $P = 0.110$

Table 7: Crop production index and fertilizer use efficiency (in parentheses) of the groundnut-rotation as **affected** by soil amendment.

Nutrients added kg/ha (N+P ₂ O ₅ +K ₂ O)	Fertilizer	Stable manure	Cow dung
0 ¹	1.00 ² (-)	1.66 (-) ³	1.83 (-)
90	2.10 (16.1)	2.16 (17.0)	2.17 (17.1)
120	1.89 (9.8)	1.93 (10.2)	1.92 (10.1)
150	1.90 (7.9)	1.84 (7.4)	1.86 (7.6)
180	2.10 (8.0)	2.00 (7.3)	2.23 (9.0)

1. **No nutrient** added as **mineral fertilizer**.
2. Crop production index (1.00 = 1192 **kg/ha** groundnut pods + 125 **kg/ha** millet grain Yields **over** the rotation **period 1997- 1998**.
3. Fertilizer use efficiency, kg produce kg⁻¹ of **nutrient** applied.

Productivity of the groundnut-millet rotation

The output (**pod +grain** yields) of the groundnut-millet rotation **system** (Table 7) is shown to be enhanced more by the integrated **fertilization** strategy than the use of mineral fertilizer alone when **compared** to the **control**. Manure and fertilizer when applied alone increased output by 75 and 99% respectively. On average, manure + fertilizer increased output by 102% and at lower levels of applied fertilizer, **combined fertilization** was 7% more **efficient** than **fertilizer** alone.

A **common assumption** is that a groundnut-millet rotation system is the maintenance of soil **fertility** through **nitrogen** fixation by the groundnut **crop**. Analyses of long-term experiments from Semiarid Francophone Africa indicated that **nutrient** balances are **negative** particularly in nitrogen, are especially negative given the **typically low**, less than 10 **kg/ha (N + P₂O₅ + K₂O)**, fertilizer usage. Studies in Bambey, Senegal (Pieri 1995) using ¹⁵N **concluded** that a groundnut **crop actually** causes **nitrogen** impoverishment of the soil **under** the **current** condition of farming (i.e. no return of residue to the field).

B. Soil conditions

Soil amendments (Table 8) tend to **enhance** the **resource** base through a positive influence on **most** of the measured **soil** chemical properties. Resource-base farming (control) or **nutrient** balance negative farming in **comparison** is depleting of **soil nutrient** reserves as measured by **soil** chemical properties..

Manure or manure + fertilizer tends to increase soil chemical measures of **nutrients** than **fertilizer** applied alone, **especially** on **soil** organic matter content (SOM), exchangeable bases (K and Ca) and total nitrogen. **After one** application, manure and manure + fertilizer plots showed a SOM content of 13 and 17% respectively, more than plots that received fertilizer alone. **After** the second application in year two, SOM

content **resulting from** manure was higher than that of the fertilizer alone by 22 and 26 % respectively.

The wide gap in SOM content. between fertilizer alone plots and manure + fertilizer plots was a result of higher **annual SOM** loss (k%) **from** the fertilizer alone plots. Soil organic **matter** loss **can** be due to both **mineralization** and **erosion**. Fertilizer was applied as **nitrogen** in year two **and nitrogen fertilizers** are known to hasten SOM mineralization through increased **microbial activity**.

The loss of soil **productivity** is **often** related to loss in organic **matter**. Soil analysis **from** long-term experiments in the West African Sahel has **indicated** that decline in soil productivity **can** be **ascribed** to two processes: the decline in soil organic **matter** and soil **acidification** (Pieri, 1995.) For example, in the **very sandy** soils of Bambey (Senegal), **annual** plowing **combined** with fertilizer leads to an annual k% of 5% or more. **Also**, on **better-textured** soils, (silt + clay > 10), of **Saria** (Burkina Faso) and **Bebedje** (Chad), the higher the N **fertilizer** used the higher the k%. The lower k% for manure + fertilizer **may** be as result of addition of organic **matter**, directly or indirectly acting as strong **check** on decomposition of the soil humus.

Benefits of manure **can** be through the physical and physio-chemical **effect**, and provision of plant **nutrient** notably N, P and K and also some micronutrients. Soil organic **matter** is increased **and** this **usually** leads to improved moisture infiltration and increased **water-holding capacity**.

Complementary **effects** of manure and mineral fertilizers have been **confirmed** in the tropics; Richards 1967, Roche 1970, **Lamarc** 1972 and Ganry et al 1974 (all **cited** in **Mokwunye** 1980). Higher yields are achieved when the **same** amount of **nutrient** is applied in **combined** form than applied as fertilizer alone. **This** is said to be true in the **long-term** and when the level of mineral fertilizer is relatively low.

Table 8: Effect of **Different Soil Amendments** on Measured Soil Chemical properties.

	pH (water)	Avail. P ppm	Exch. K ppm	Exch. Ca. ppm	OM %	k %
Year 1 = Groundnut and Phosphorus						
Control	6.2	8	25	178	0.92	-
Fertilizer	6.5	75	23	162	0.64	-
Stable manure	6.2	15	25	123	0.79	-
cow dung	6.1	13	19	129	0.64	-
Stable + Fert.	6.1	14	28	168	0.80	-
Cow dung + Fert.	6.1	23	26	181	0.70	-
Year 2 = Millet and Nitrogen						
Control	5.8	9	-	-	0.68	14
Fertilizer	5.8	5	-	-	0.49	12
Stable manure	5.7	5	-	-	0.63	10
Cow dung	5.7	7	-	-	0.57	6
Stable + Fert.	5.5	6	-	-	0.63	11
Cow dung + Fert.	5.7	6	-	-	0.60	7

3. Conclusions

The **results** of the integrated **fertilization** experiment **lead** to the **conclusion** that there is a threat of **soil** productivity **decline over time** under the **current** cropping **practices**, no fertilization or **mineral** fertilizer alone. **In** order to **maintain crop** yields under **continuous** cultivation there is the need for **additional soil** amendments. **Fertilizers** are **essential** under **such** stressed **soil** conditions, but are **expensive** inputs, and **must** be **well managed** to **maximize efficiency**.

Though there was variation in the two years **between** the two **manures**, regardless of **the** type, manure and fertilizer **combined** always **outperformed** the **fertilizer** alone.

The **exclusive** use of fertilizer on **fragile** ecosystems as the **coarse-textured** **uplands** of **The Gambia**, may **lead** to physical land degradation and **ultimately** to **nutrient** fatigue. The **solution** is then an integrated plant **nutrient system** approach, by combining mineral fertilizers with organic **ones such** as manure. The addition of manure **can** improve the properties of these **fragile soils** as soil organic **matter** content for **sustainable** agricultural productivity.

The integrated fertilization strategy employed in this **study** has **increased** the productivity of groundnut-millet rotation by **increasing** fertilizer use **efficiency over** **mineral** fertilizer especially at low rates of applied fertilizer, thus **reducing** production **cost** and **increasing** profit.

Recommendations

There is need for the **study** to continue **over** the long-term in order to **identify** key indicators of **soil** fertility **decline** relating to **soil** organic **matter** content. This **may** help us to **understand** the soil causes of land degradation and establish critical **values** of soil organic **matter** for **different** agroecologies.

For a large-scale adoption of **manure** use on field **crops**, there **is** the need to facilitate the transportation of **manure from** the source to field as this is the principal **constraint** especially for the fields far away **from** dwellings.

To increase the value of manure, proper field storage methods need to be recommended. Manure is transported to the field before the rains and at this time **can** only be surface applied which exposes it to the elements (heat, **wind** and rain) of the weather.

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Annex 1 : Individual Analysis of variance of Groundnut Pod yield per Site.

Source of Variation	Degree of Freedom	Sums of Squares			
		Yundum	Njaba Kunda	Jenoi	Sapu
Replication	3	1220433.625	792740.477	375356.279	3402314.704
Manure (M)	2	1325016.346*	113592.655	78072.589	460474.455
Fertilizer (F)	4	173729.313	2936851.740*	317219.280*	463136.568
M x F	8	2961125.678*	1206037.055	240260.751	
864467.625					
Error	42	333370.672	8052259.578	868654.830	428692.1398
c v (%)		20.81	22.39	20.13	24.37

***Piliostigma reticulatum* used for Soil Organic Matter Build up: Effects on the Soil Quality and Crop Yield in the Peanut Basin of Senegal**

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Abstract

Given the **high** demand for **crop** residues **and** the **insufficiency** of animal **manure**, the use of **naive** vegetation **could** be an alternative solution for improving **soil quality** and **crop** productivity. **This** study was conducted to determine **the effect** of *Piliostigma reticulatum* (PR), a native shrub, in improving the soil properties of a degraded soil **and** to develop management systems that effectively utilize **the** species to **maximize input** efficiency and **crop** productivity. The experiment was conducted at Nioro, Kaolack, on a **Deck Dior** loamy sand (fine **sandy**, mixed Haplic Ferric **Lixisol**), leached ferrugeneous soil tropical **soil**, where peanut and millet were grown. The above-ground biomass of **PR**, collected **after each cutting** from the field was applied at the **soil** surface, at a rate of 2 **t/ha** on the dry **matter** basis. The study **compared** a control (TO), PR biomass **from weeding** (T1), T1 + mineral fertihzer (T2), at recommended rate for the **growing crop**, T2 + biomass **from cutting after** harvest (T3), PR biomass fi-om clear cutting **during** soil preparation (T4), and T4 + minerai fertihzer at recommended rate for the **growing crop** (T5). As treatment application was **sequential**, partial results showed slight increases of 21 **and** 26% for T1 and T2 respectively in peanut plant population, 6 and 17% for T 1 and T2 respectively in pods. As for millet, increases in stalk of 8 and 188% for T 1 and T2 **respectively** were recorded. For both **crops**, these increases in yield components were more likely due to the chemical fertilizer that is more available **to** plants so far.

Key words: *Piliostigma reticulatum*, biomass, soil organic matter, soil qualii, crop productivity.

1. Introduction

With 1/3 of the **country's** area, the Peanut **Basin provides** 75% of the peanut and 80% of the millet production of the country. However, **while** the soils are **intensively** culivated with a high degree of land **utilization** (land in fallow is less than 3%), **crop** production is still low. **Soils** are degraded.

Degradation of the soil **resource**, in **Senegal**, has resuhed **from** the combination of decreases in **rainfall**, inappropriate land management practices (less land in shorter **fallow** periods, **removal** of nearly all **crop** residues fi-om fields), and **declining** numbers of trees **from** traditional **parkland agroforestry** systems. Consequently, there has been an intense extraction of **nutrient N and P**, and a decrease in overall **soil organic matter** (decreased **from** the **naturally** occurring 2% **down** to 0.3%). The changes to the **soil resource** h.ave **caused** a decrease in food production and reduced rural income. Therefore, efforts must be redoubled to replace **nutrients** fh.ave been **lost** fi-om the farms through the use of fertilizers and organic **matter**. Given the high demand for **crop** residues **and** the **insufficiency** of **animal manure**, the use of **native vegetation** **could** be an alternative **solution** for improving **soil quality** and thereby **increasing crop** productivity.

Piliostigma reticulatum, an endophytic legume, has no nodules, **does not fix N**, belongs to the *Cesalpiniaceae* family, and **is** usually a shrub but it **can** occasionally be a tree. It grows on **sandy**, clayey and lateritic **soils**. **During** the dry season, it **can** grow up to 90 cm with a canopy diameter of 100 to 175 cm. Annually, 1268 g of dry weight biomass per shrub are **produced**, for an average density of 317 **shrubs** per ha (Diack et al., 1998). In some **areas**, these **shrubs** nearly **cover** the landscape but in **others**, there is a less dense distribution. This **difference** in density is due to **differences** in soil types. If **left uncut**, these shrubs continue to grow, but in **farmers'** fields they are **cut** at the soil surface and burned just prior to the **rainy** season.

A survey was conducted (Diack et al., 1998) to determine the **farmer's** level of **appreciation** and the uses of *P. reticulatum* within the parkland system. The survey showed that *P. reticulatum* was the third most important species that **farmers** would like to conserve *in the* fields **after two** tree species: *Cordyla pinnata* and *Acacia albida*. The reasons for the **choice** of these three species were fruit production, **nutrient** value of their biomass and forage for **livestock**. For *P. reticulatum*, farmers thought that it **can** play an important role in soil **fertilization** and help protect soil against erosion. The population of *P. reticulatum* is still acceptable despite a decrease **during** the past ten years, due to **mechanization**. The management **system** of *P. reticulatum* **consists** of **cutting** the shrub (**april-june**) for soil preparation and **cutting** 2 to 3 times more, depending on the **crop**, **during** the growing season. Ash as mineral **fertilizer** is the main **product** that farmers get from the management **system**. According to **farmers**, the **effect** of *P. reticulatum* on **crop productivity** is showed by the good response of **crops such** as peanut, millet and to some extent cowpea, under the shrub canopy. These information **collected from** the survey show that *Piliostigma reticulatum* plays an important role in the farming system and has a potential of improving the soil **productivity**.

A decomposition **study** of *Piliostigma reticulatum* biomass (Diack et al., 1998) showed a greater mass loss under field conditions than under controlled conditions. This was probably due to the role of soil **fauna which may** have been involved **under field** conditions but would have **been** excluded **under** laboratory conditions. With **such** a fast decomposition rate **under field** conditions, accumulating residue biomass at the soil **surface would** certainly avoid a **discontinuous** distribution of organic **resource** for the microbial **activity**. The **specific** surface **area-to-mass** ratio, obtained for *P. reticulatum*, should allow **such** a **continuous** application of the biomass to the **soil** for both **cover** and organic **matter** build up.

The objectives of this study are to determine the influence of *P. reticulatum* on the **soil** physical, chemical and biological properties and the **crop** yield.

2. Materials and Methods

Site : The experiment is being **carried out** in Paoskoto (Kaolack) in two farmers' fields which are under a **two-year** rotation of peanut (*Arachis hypogaea*) and millet (*Pennisetum glaucum* L.). The soil is a Deck Dior **loamy sand** (fine-sandy, mixed Haplic Ferric Liisol), leached **ferruginous** tropical soil (probably an Ultisol). The soil has a pH **varying from** 5.7 to 6.7 and a low **fertility status** (OC: 0.47%, N: 0.45%).

Materials:

The above-ground biomass (leaves and stems) of *Piliostigma reticulatum* were collected **after each cutting** from the field.

Experimental design

The design was a randomized **complete block** design with 6 treatments replicated 4 times.

The treatments are the following:

T0 = Control;

T1 = Biomass from cutting (weeding) and application between rows and at the soil surface, at a rate of 2 ton/ha of dry matter;

T2 = T1 + mineral fertilizer at the recommended rate for the growing crop;

T3 = T2 + biomass from cutting after harvest and application at the soil surface, at a rate of 2 ton/ha of dry matter;

T4 = Biomass from clear cutting (soil preparation) and application at the soil surface, at a rate of 2 ton/ha of dry matter;

T5 = T4 + mineral fertilizer at the recommended rate for the growing crop.

Peanut, a 73-33 variety, will be planted with inter-rows of 0.50 m while millet (Souna 3) will be planted with inter-rows of 0.90 m, in an experimental unit area of 45 m².

Measurements

On plants: N, P, K, Ca, Mg and S contents will be determined at the maximum vegetative stage and before harvesting for each crop.

On soils: samples will be collected before and after each growing season to monitor soil moisture in relation to soil physical, chemical, biological properties and C dynamics. The following properties will be measured:

- Physical characteristics:** moisture content, bulk density, infiltration rate, soil resistance to penetration and sealing index as a measure of aggregate stability;
- Chemical characteristics:** total C and N, NO₃⁻, NH₄⁺, P₂O₅, K⁺, Ca²⁺ and Mg²⁺;
- Biological characteristics:** microbial biomass C, particulate organic C (POC) and enzyme activity (β -glucosidase).

Field Operations during the first year

Field Operations	Dates of Implementation	
	Peanut	Millet
Sowing	07/21	07/21
1 st weeding	08/18	08/07
Thinning	-	08/07
N-P-K application	08/19	08/13
1 st urea application	-	08/19
2 nd urea application	-	09/04
<i>P. reticulatum</i> application	9/04	9/04
2 nd weeding	09/08	09/08
Harvest	11/17	11/9
<i>P. reticulatum</i> application	12/11	12/11

3. Partial Results and Discussion

Since the application of *Piliostigma reticulatum* biomass is sequential, treatment T3 has been applied right after harvest while T4 and T5 will be applied early next season. Therefore, the yield components presented in Tables 1 and 2 are only for treatments T0,

T1 and T2. The yield components recorded for T3, T4 and T5 treatments could be considered as control for the first year.

For peanut (Table 1), even though yields were relatively low, the *P. reticulatum* application has resulted in a slight increase in yield components. For plant population at harvest, there is an increase of 21 and 26% for treatments T1 and T2, respectively. For pods, there has been an increase in yield of 6 and 17% for T1 and T2, respectively whereas 6 and 29% were the respective increases in peanut hay yield for T1 and T2.

As for millet, yields in general were low (Table 2). However, while treatment T1 has not yet shown any increase, T2 in the other hand has resulted in a strong yield response. Plant population has increased from 1 to 6% and stalk from 8 to 188% for T1 and T2, respectively. For both crops, increases in yield components were more likely due to the chemical fertilizer that was added to *P. reticulatum* biomass for its greater availability.

Perspectives

Since the experimentation is a 4-year program, we need to complete first the treatment applications and then monitor the soil property changes over time.

Table 1. Yield components of the peanut as affected by *Piliostigma reticulatum*

Treatment	Plantpopulation	Pod+Hay (kg/ha)	Hay (kg/ha)	Pod (kg/ha)
TO(Control)	44480	1250	600	650
T 1 (2 tons biomass)	54060	1320	640	690
T2 (2 tons biomass + mineral fertilizers)	55980	1530	770	760
Mean	53300	1460	720	750

Table 2. Yield components of the millet as affected by *Piliostigma reticulatum*

Treatment	Plantpopulation	Number of spikes /ha	Stalk (kg/ha)	Grain(kg/ha)
T0	8240	11140	1240	210
T1	8320	8170	1340	150
T2	8700	27170	3560	660
Mean	8380	18650	2040	410

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Phosphogypsum Efficiency to correct Soil P Deficiency and/or Soil Acidity

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Abstract

To **increase** agricultural production in Senegal, the national program uses a phosphogypsum (PG) and Taiba phosphate rock (PR) mix as a **soil P** amendment to correct **soil P** deficiency **and/or** acidity. However, there is no previous study demonstrating the efficiency of PG to **correct these soil constraints**. This long **term** experiment started in 1997 at Nioro agricultural research station to study the efficiency of PG as compared with PR and lime to increase **crop** yields for the **corn/peanut** rotation and improve **soil P** and pH **status**. For the degraded **soil** fertility site selected, a randomized **complete block** design **composed** of 8 treatments **and** 4 replications is used.

In 1997, no **significant** direct **effect** was observed on **corn** yield components. This **can** be explained partly by **rainfall** shortage. The analysis of **soil** samples taken **after** harvest has shown a important Ca movement within the soil profile. **In** 1998, the residual **effect** of **treatments** is **significant** only on pod yield. The positive **effect** is more important for the lime treatment. As compared to the control, **all** the treatments (**except** the 75 % PR and 25 % PG combination) **significantly** improved the pod yield. This **confirmed** the positive **effect** of Ca application on the pod **filling**. The foliar analysis has not **shown** **any significant** treatment **effect**, **despite** the plant **chlorosis** observed.

1. Introduction

The production of **inorganic** fertilizer phosphate **from** the local industrial produces phosphoric **acid** and the natural rock phosphate deposits **result** in a huge amount of **phosphogypsum** by-product **piled** up near the factories. This materials for which chemical characteristics are given (see **annex**) is now being used on a large **scale** (nationwide) for the national program aiming at increasing the agricultural production. The newly processed P-source amendment material bags distributed to farmers **consists** of the mix of of 50 % rock phosphate (RP) and 50 % phosphogypsum. There is, however, no previous study in Senegal that documents the efficiency of PG to correct **soil P** deficiency for **crop** uses, or to reduce soil acidity **given** the large Ca content.

The objective of this experiment was to study the efficiency of PG as compared with rock phosphate and lime.

2 .Materials and Methods

Site selection

This long **term** experiment, started in 1997, was located in the NIORO ISRA **agronomic** research station in a **ferruginous**, leached soil. For the put-**pose** of this study, a highly chemically degraded soil site (pH < 5.5) but with available P < 30 ppm was selected. This had been enabled by the soil fertility assessment undertaken throughout the **research** station three years ago, (Agetip, 1995). The 2C m by 20 m grid **sampling** used **allowed** a spatial variability analysis of the various plots **within** the station.

Cropping system

The Nioro **area** receives relatively reliable rainfall. **Peanut** (variety 73-33) is often

grown as a cash crop as is corn (variety Synthetic C) which is very sensitive to soil fertility. The corn/peanut rotation was started in 1997 with corn. The potential yield of the region is 4 t/ha for corn, and 2,5 t/ha for peanut.

Treatments

Treatments under comparison consisted of the combined use of phosphogypsum and rock phosphate as indicated (Table 1) ; the lime treatment acted as a reference for soil acidity control.

Table 1: Treatments under comparison

Treatments	Specifications
1.	Check : No P added, only N and K
2.	0 % P from rock phosphate (RP) + 0 % P from phosphogypsum (PG) + 30 kg/ha P ₂ O ₅ from triple superphosphate (TSP)
3.	0 % P from RP + 100 % P from PG
4.	25 % P from RP + 75 % P from PG
5.	50 % P from RP + 50 % P from PG
6.	75 % P from RP + 25 % P from PG
7.	100 % P from RP + 0 % P from PG
8.	100 % Ca from lime (CaO)

The rate of application was different for the two P sources : 100 % P from RP corresponds with an application rate of 400 kg/ha of RP, and 100 % P from PG defines an application rate of 700 kg/ha of PG. For treatment 8, 100 % Ca from CaO refers to a lime application of 400 kg/ha. From the chemical analysis data of these fertilizers, the P and/or Ca quantity added on each plot can be determined. These rates will be applied once every 4 years after 2 complete rotation.

Experimental design

The experimental design was a randomized complete block design with 8 treatments and 4 repetitions. The size for each of the 32 plots is 84 m² (15 m x 5.6 m). The number of rows to be sown each year depend on the crop : 7 for corn sown at a spacing of 80 cm and 11 for peanut sown at a spacing of 50 cm

Measurements

a) Soils

After the initial soil physical and chemical characterization, as described above, soil samples are taken once a year after harvest to monitor soil pH, P and Ca contents within the profile. For the first sampling performed in December 1997 after the corn harvest, 108 samples have been collected according the following scheme :

- For treatment 1, 3 and 7, all the plots were sampled at 4 depths (0-10, 1 0-20, 20-40, and 40-60 cm) The treatments have been chosen to allow a analysis of Ca movement in the profile ;
- For the remaining treatments, all the plots have been sampled at only 3 depths (0-10, 1 0-20,20-40 cm)

The soil analyses run on those samples were : particle size analysis, pH (water and KCl), carbon, nitrogen (total N and nitrates), bases, CEC, aluminum and sulfur.

b) Plant

This sampling was not done in 1997 for com.

Peanut plant samples are taken from each of the 32 plots at flowering/pegging stage

for foliar diagnosis. For **each** plot, four replicate samples were analyzed for N, P, K, Ca, and Mg.

Field operations

After applying the phosphocalcic amendment, the plots were plowed to mix the fertilizer in the top 20 cm soil layer. The timing of the **different** operations performed in 1997 for **corn** and in 1998 for peanut is presented (Table 2).

Table 2 : Field operations during the 1998 cropping season

Operation	Date of implementation	
	Corn (1997)	Peanut (1998)
RP, PG or Lime application	07/02	-
Oxen driven plowing	07/03-04	-
Sowing	07/10	06/21
N-K application	07/02	07/27
Thinning	08/05	-
Pre-emergence weeding	-	07/27
1 st weeding	08/05	08/10
1 st urea application	08/05	08/
2 nd urea application	08/25	-
2 nd weeding	08/25	08/21
Bedding	09/01	-
Harvest	10/31	11/06

Nitrogen and Potassium were applied on **each** plot at the **following** rates :

12 **kg/ha** of N was applied at sowing, 22 **kg/ha** N was applied for both applications to **corn** ; 12 **kg/ha** of N was applied at sowing for peanut

40 **kg/ha** of K was applied at sowing for both peanut and **corn**.

Rainfall conditions

Rainfall patterns were **different** for the 2 years. In **fact**, the rainy season of 1997 was ended early while rainy season in 1998 was **late**. The total **annual rainfall** was **about** the **same** for the 2 cropping seasons (580 mm). However, **while** the rainy season started early **June** 1997, the first important rain was recorded **late** July 1998. Although characterized by a rather short rainy season, the 1998 cropping season had a **much** better **rainfall** distribution. A long drought period occurred early **during** the 1998 cropping season, **causing** a severe plant water stress, while in 1998 there were no major water stress problem, **except** at the **crop maturity** phase.

3. Results and Discussion

As mentioned above, the selected site is part of the most degraded **block** of Nioro Station. The **comparison** of the **effects** of P and/or Ca amendments on **corn** in 1997 and on peanut in 1998 is **shown** in table 3.

For the **first year** of the **experiment** corresponding with **corn** production, the ANOVA indicated no **significant** treatment effect. An important variability has been observed **among** treatment. Corn grain yields obtained were low **compared** to the variety yield **potential** which is around 4 tons/ha. Two severe drought periods have **occurred** during the cropping season, early in the vegetative phase and late at the maturity phase, which partly explains the low yield obtained this year in the **Peanut Basin**.

Treatment	Corn (1997)			Peanut (1998)			
	Number of ears	Stalk (kg/ha)	Grain (kg/ha)	Plant population	Pod + Hay (kg/ha)	Hay (kg/ha)	Pod (kg/ha)
Check (T1)	18330	930	732	84270	3930	2580	1350 d
30 P ₂ O ₅ (T2)	18330	1550	1072	87500	4150	2670	1480 c
100 % PG (T3)	23610	1312	1110	82760	3990	2800	1590 b
25 -75 (T4)	21670	1240	970	81350	4260	2370	1590 b
50-50 (T5)	17920	1000	740	86510	4530	2900	1630 ab
75 -25 (T6)	19760	910	780	75100	3760	2370	1390 d
100 % as RP (T7)	17470	990	730	86040	4330	2800	1540 bc
Lime alone (T8)	18890	980	750	86350	4380	2720	1660a
Mean	19580	1150	880	83740	4170	2640	1530
Level of sign	NS	NS	NS	NS	NS	NS	S
CV%	25.2	39.2	44.2	7.9	11.5	16.6	7.8

In 1998, no **significant effect** is observed **except** for pod yields. Highest pod yields were obtained with the treatment where lime was applied and by the treatments where **phosphogypsum** was added; the best **among** these was the treatment receiving the **mix** of 50 % PG + 50 % RP. This **indicates** the relative importance of Ca in pod production. The positive action of Ca to the degraded soil **could** arise **from two** aspects. First of **all**, there is the improvement of pod **filling**, and secondly the soil pH increase **and/or aluminum toxicity** decrease could **occur**. This **can** be **confirmed** by the soil profile Ca enrichment **resulting** from the **different** P or Ca source amendments. This hypothesis is **supported** by the **fact** that the plant **analysis done following** the chlorosis observed at mid-season **does not reveal any significant treatment difference**.

4. Conclusion

After a second year study, the trials show the possible **effects** that **can** result from the P **and/or** Ca source of soil amendments. The remaining 2 to 4 years of the experiment should **give** a better idea on the real **agronomic** value of phosphogypsum as an amendment material.

Annexe: Chemical characteristics of **phosphogypsum** (PG), PG + Taiba Rock Phosphate (RP) mix, **and** Taiba RP

Total Elements	PG	50% PG + 50% RP	Taiba RP
CaO %	32,3	40,6	49,4
MgO %	0,01	0,04	0,06
K ₂ O %	< 0,5	< 0,5	0,02
Na ₂ O %	0,07	0,08	0,09
Fe ₂ O ₃ %	0,15	0,49	1,59
Al ₂ O ₃ %	0,27	0,77	0,98
P ₂ O ₅ %	0,99	19,12	37,2
S %	14,64	6,79	*
Mn ppm	2,3	108	404
Cu ppm	3,5	27,7	72
Zn ppm	< 1.0	290	522
Pb ppm	5,3	5,3	5,4
Cr ppm	24,2	96,7	198
Ni ppm	2,8	29,8	86,4
Cd ppm	15,8	51,6	70,8

Soluble elements

Samples

CaO %	10,48	10,9
MgO %	0,01	0,03
K ₂ O %	0,44	0,32
Na ₂ O %	0,07	0,07
P ₂ O ₅ %	0,39	0,47
S %	4,86	4,81
pH eau %	4,67	3,91

Phosphorus Buffer Coefficients of Selected Soils of West Africa

A. Sidibé, M. Keïta, O.B. Coumaré, M.D. Doumbia, A. Bationo, R. A. Kablan et R. S. Yost

Abstract

Laboratory incubations were conducted to **validate** P **buffer** coefficients predicted by the Phosphorus **Decision** Support System (PDSS) **model**. Soil samples were **analyzed** for general soil properties.

Collected soil samples were **first analyzed** for **clay** and plant available P. These parameters were **fed** to the model to generate **buffer** coefficients referred to as a_m . These soils samples were then incubated to **estimate** buffer coefficients referred to as a_i . **Then**, a_m and a_i were **compared**.

Steeper slopes (indicating higher buffer coefficients, but **lower buffering capacity**) were obtained for **sandy** soils (0.87 for the **sandy, Seno** soil), in **contrast** to the **less** steep slopes for clayey soils (0.21 for the clayey, **Moursi 1** soil). Buffer coefficients derived **from** the model (a_m) were significantly higher than those obtained **from** laboratory incubation (a_i). **Differential** responses of soils to methods of **buffer** coefficient **determination** were obtained: the buffer coefficient derived **from** the model (a_m) was **significantly** higher for the clayey **Moursi 1** soil (under irrigated rice), but not for the clayey Longorola BF soil (bottom-land, waterlogged soil).

Future work on PDSS will **focus** on (i) field testing of the **predictions** and (ii) **including** phosphate rocks into the **predictions**. Phosphate rocks **will require** defining both specific P buffer coefficients and soil P depletion rates in relation with phosphate rocks.

1. Background

It has long been believed that **rainfall** was the most limiting **factor** for **crop** production in Mali as well as in **many** regions of West **Africa**. Recently, **many** research programs have **provided** evidence that soil **fertility**, not **rainfall** is the number one **factor limiting** crop production in these **regions**. (Stroosnijder, 1981; Doumbia et al., 1998; Breman et al., 1998). Phosphorus is the most **deficient** and is the plant growth limiting **nutrient** in these soils (Poulain, 1976; Manu et al., 1991; Daumbia et al., 1993). Jones and Wild (1975) **documented** that P deficiency **could** be so **acute** that plant growth stopped once the seed reserve of P had **been** depleted.

Fertilizer recommendations in Mali were made according to Chaminade (1965). For economical **reasons** deficiency corrective rates were recommended (Piéri, 1973). For the case of P, rates of **about** 20 kg ha⁻¹ are recommended for most **crops** in most soils of Mali (Poulain, 1977). When applied, these rates **lead** to **soil mining** (Van der Pol, 1992; Kieft et al., 1994).

For increased **crop** production and sustained soil **fertility**, there is a need for **recommendations** based on **factors** such soil properties, yield goal, etc. These site **specific recommendations** are **better** handled by **decision** aids. Phosphorus **decision** support system (PDSS) offers a strong potential in making these **recommendations**. It gives P **recommendation** on the basis of primarily soil **clay** and plant available P contents (Yost et al., 1992). However, the **model** needs to be adapted to soil and socio-economic conditions of West **Africa**. Phosphorus requirement

predictions are made according to the following formula:

$$P = (Bc - B_0) * a_1/a_2 * D/10, \text{ where}$$

P = P requirement **prediction**,

Bc = P **critical** level in the soil,

B_0 = P initial level in the soil,

a_1 = **long** term retention rate of P

a_2 = P **buffer coefficient**,

D = depth of application.

3. Objectives

The general objective of this research was to test the PDSS model. The **specific** objective was to test **P-buffer coefficients** determined by PDSS.

4. Materials and Methods

Forty five soil samples representing major **agricultural** regions of Mali and Niger were selected on the basis of texture **class**. These samples were analyzed for **clay** content, **Bray-1 P**, and pH (Spark et al., 1996).

Laboratory incubations were **performed** to determine P buffer coefficients in the laboratory. These coefficient were compared to those predicted by PDSS. Known rates of P solutions were added to **soil (1: 1)**, and the mixture were allowed to dry at room temperature **during** 6-7 days. The slope of the **regression** obtained by **plotting** P^{-1} extractable P against the **amount** of P added was **considered** as P **buffer coefficient** (a_i). This coefficient was compared with the coefficient (a_e) obtained by the model, according to the following formula (Yost et al., 1992).

$$a_e = 0.6665 * \exp(-0.02739 * \text{clay}).$$

5. Results and Discussions

Soils were **selected** to represent **cropping systems** and of Mali and Niger including **rainfed agriculture**, bottom land (waterlogged), and irrigated **systems**. These soil samples were **classified** into two **textural** and two **Bray-1 P groups**. The **textural groups** included: (i) the **clays** such as soils from Kollo, Niger (56.4% **clay**), **Moursi**, Mali (43% **clay**) and Longorola bf, Mali (35% **clay**) and (ii) the **sands** such as **Seno-S**, Mali (3.9% **clay**) and **Dounga S**. (2% **clay**). The **Bray-1 P** levels included: (i) soil with “**sufficient**” P such as Kollo and Longorola bf (with $>10 \text{ mg P kg}^{-1}$) and (ii) soils **very deficient** in P such as Moursi and Tanda, Niger (with $< 1 \text{ mg P kg}^{-1}$). The soils Kollo and Longorola bf had **each** high contents of both **clay** and **Bray-1 P**.

The **different** buffer coefficients are shown in Figures 1 through 7. In **general**, buffer coefficients estimated by the model are higher than those determined by incubation. In addition, **sandy** soils have higher **buffer coefficients**.

Figure 1 shows **buffer coefficients** for a **sandy soil (Seno)**, a loamy soil (**Kita**), and a clayey soil (Moursi 1). The steeper slope (higher **buffer coefficient** of 0.87) for the **sandy Seno** has a lower buffering capacity. In contrast, the less steep slope (lower **buffer coefficient** of 0.21) for the clayey Moursi 1 has a higher buffering capacity. The Moursi 1 is a soil under irrigated rice cropping system. Similarly, Figure 2 shows the same pattern between the sandy soil of Dougouba and the clayey soil of Longorola BF. The Longorola BF is a bottom-land soil (waterlogged for about 3-4 months) under rice production. Figure 3 shows the above

patterns for soil from different cropping systems of Niger.

Figure 5 compares **buffer** coefficients obtained from laboratory incubation (a_i) to those derived from the model (a_m). In **general** the model predicted **significantly** higher coefficients, as indicated by **Duncan** test. Figure 6 shows the **comparison** buffer coefficients a_m and a_i of 10 samples **collected from** major cropping systems of Mali. The model predicted a significantly higher coefficient for the clayey Moursi 1 soil (under irrigated **rice** cropping system), but not for the clayey Longorola BF soil (a bottom-land **soil**, waterlogged for **about 3-4 months**, under **rice** production).

6. Conclusions and Perspectives

For soil **containing** a wide range of **clay** content (2 to 56%), steeper slopes (indicating higher **buffer** coefficients, but lower **buffering capacity**) were obtained for **sandy** soils (0.87 for the **sandy, Seno** soil), in **contrast** to the less steep slopes for clayey soils (0.21 for the clayey, Moursi 1 soil).

Buffer coefficients derived from the model (a_m) were **significantly** higher than those obtained from laboratory incubation (a_i). This would **lead** to slight under **prediction** of P **fertilizers** requirements by PDSS in addition there were **differential** responses of soils to methods of **buffer** coefficient determination. The **buffer** coefficient derived from the model (a_m) was **significantly** higher for the clayey Moursi 1. **soil** (under irrigated **rice**), but not for the clayey Longorola BF soil (bottom-land, waterlogged soil).

In the future, **predictions** from PDSS will be tested in field plots against “**conventional**” **fertilizer recommendations**. These tests **will** be implemented with sorghum and maize.

One of the limitations of PDSS is that it **does** not make **recommendations** using phosphate rocks (PR). Attempts will be made to **include** phosphate rocks, especially Tilemsi PR into the **recommendations**. Phosphate rocks will require defining both **specific P buffer** coefficients and soil P depletion rates in relation with the use of **PR's**.

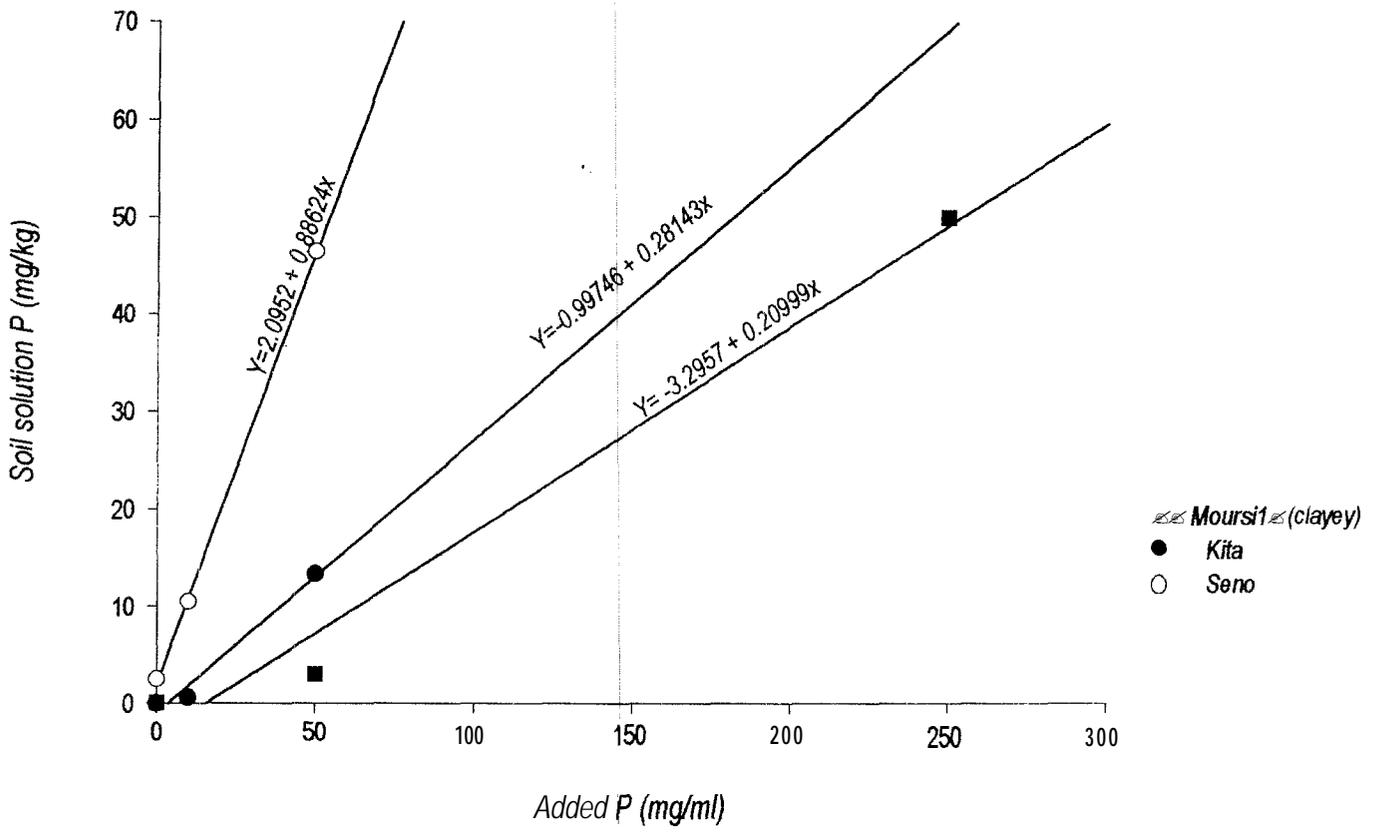
PBuffer1

Figure 7. Buffer coefficient of selected soils (Incubation method)

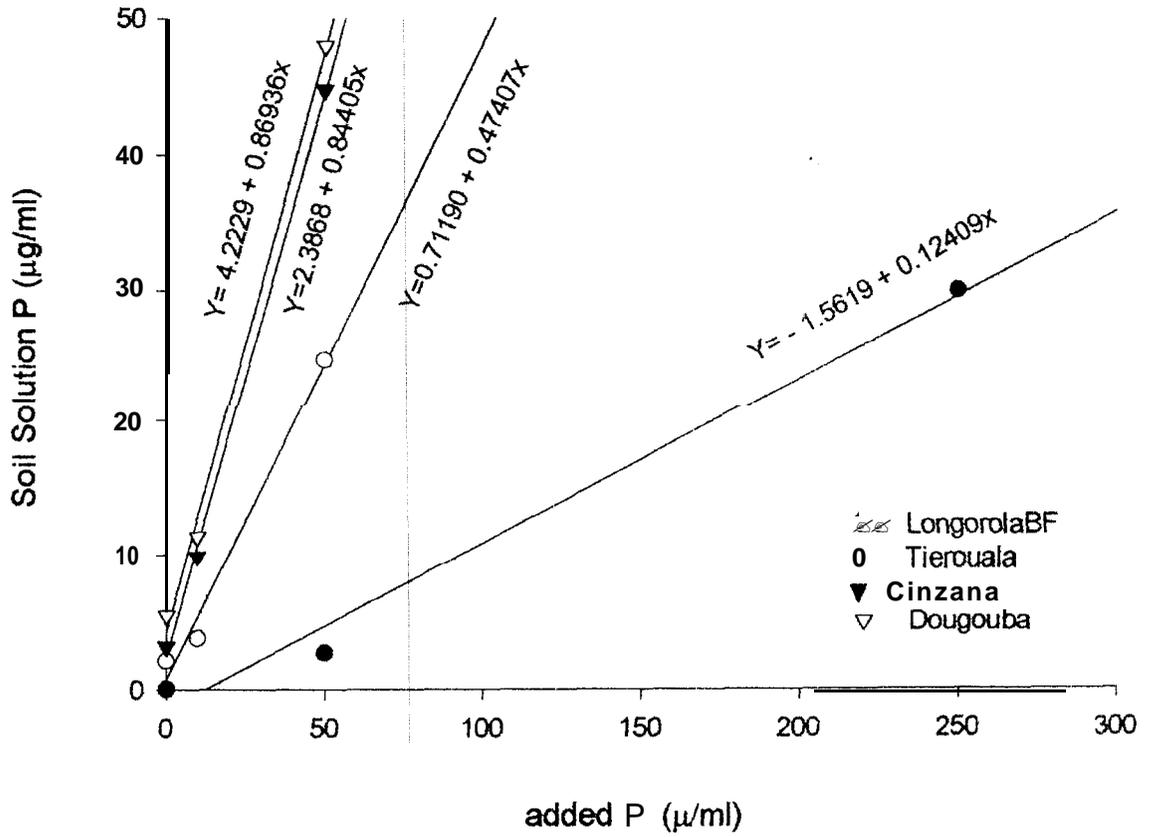
PBuffer2

Figure 2. Buffer coefficient of selected soils (Incubation method)

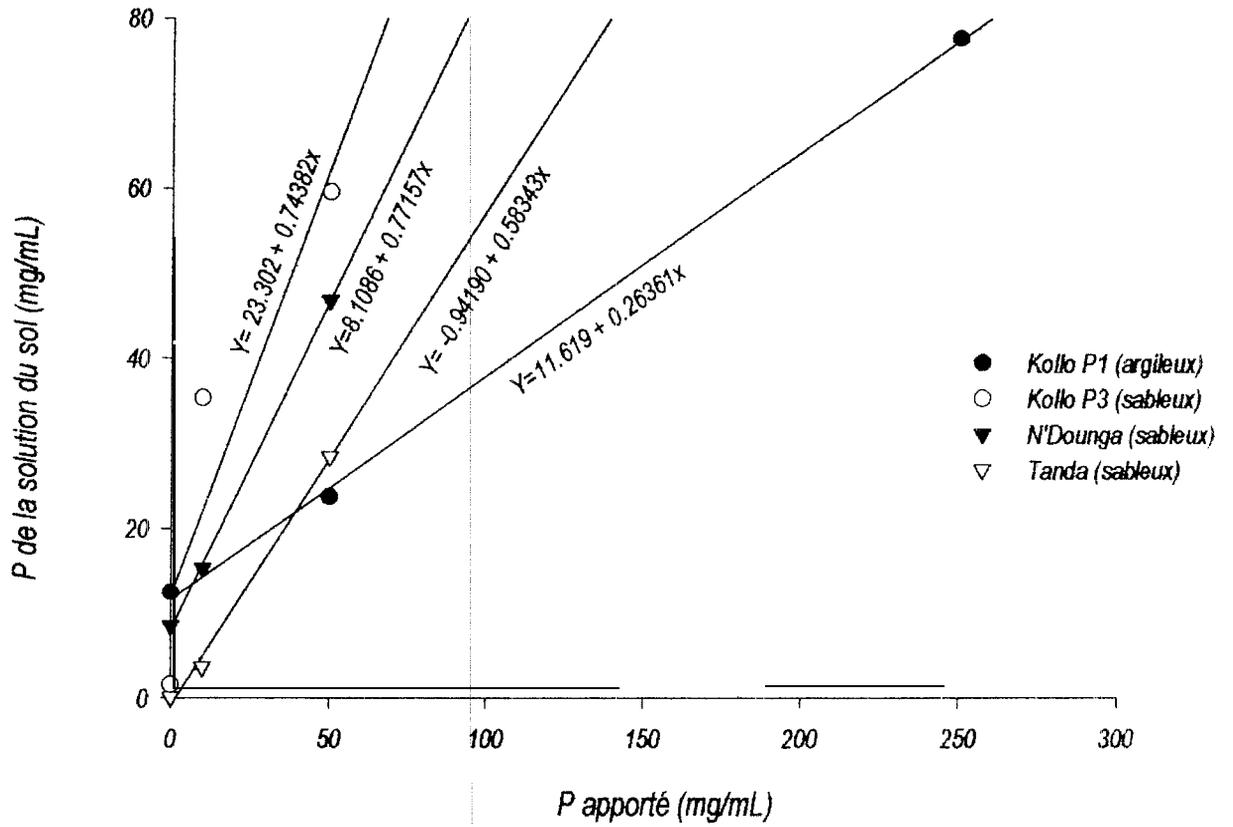
Pbuffer3

Figure 3. Coefficients de pouvoir tampon de quelques sols du Niger (méthode par incubation)

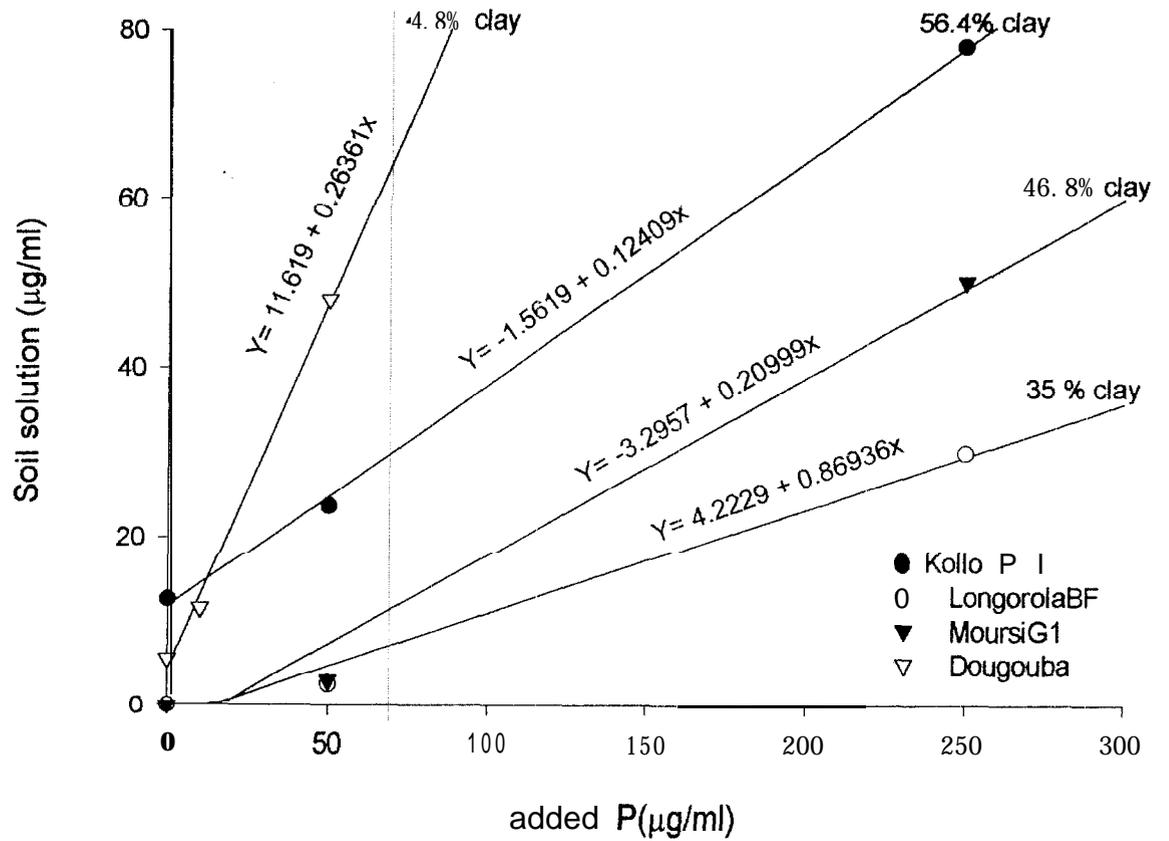
PBuffer4

Figure 4. Buffer coefficient of selected soils (Incubation method)

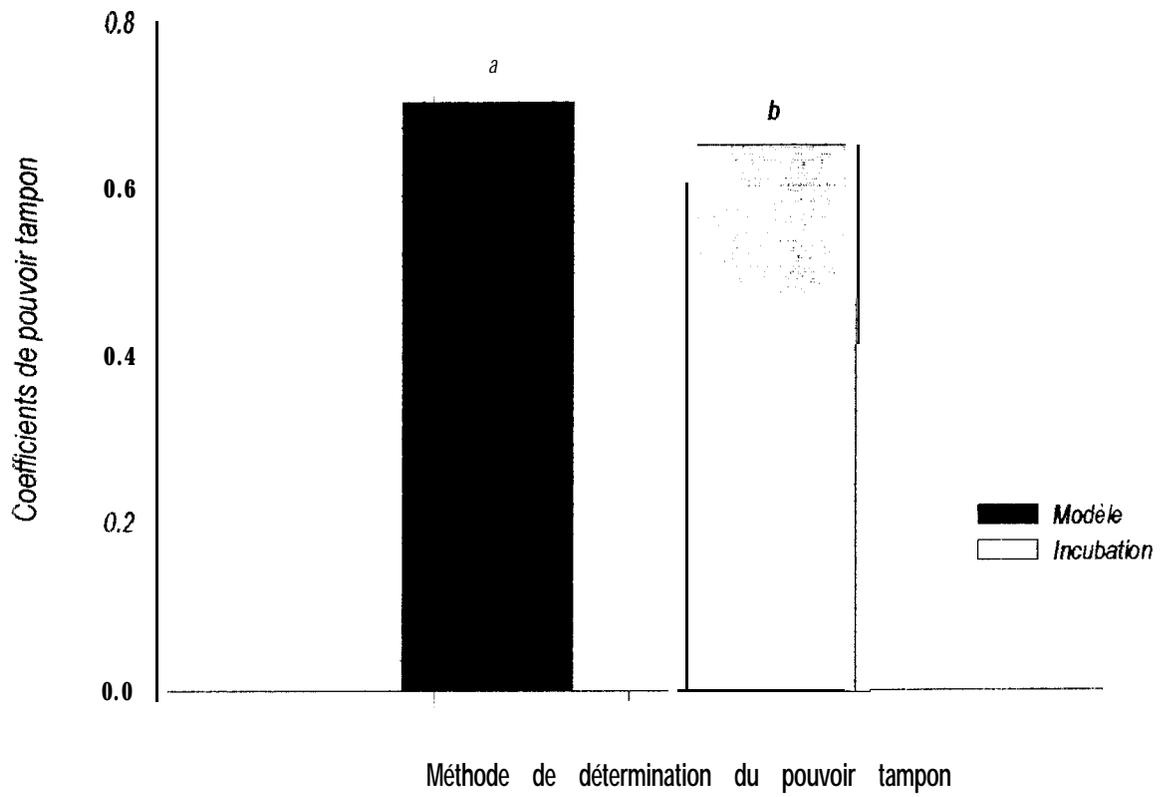
PBuffer5

Figure 5. Comparaison de méthodes de *détermination* de *coefficients* de pouvoir tampon en *P* ('a' and 'b' indiquent les classes du *test* de *Duncan*).

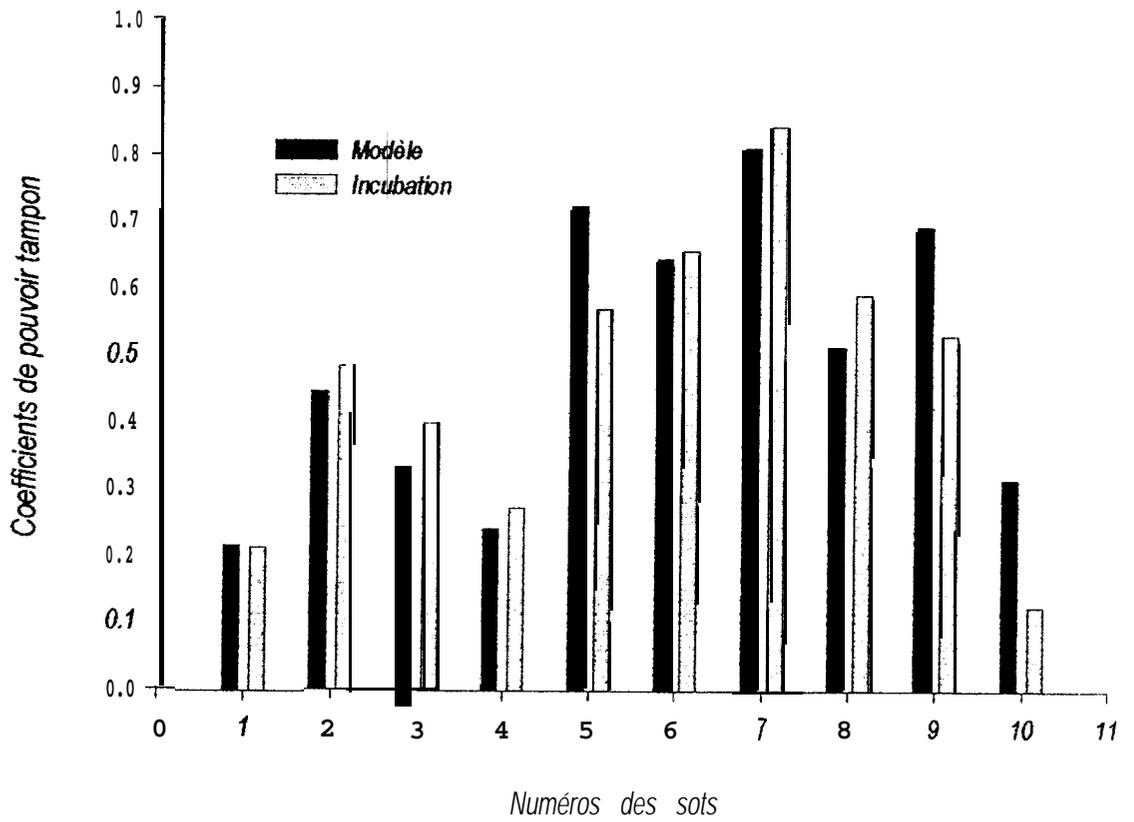
PBuffer6

Figure 6. Comparaison de méthodes de détermination de coefficients de pouvoir tampon en P de quelques sots du Mali..

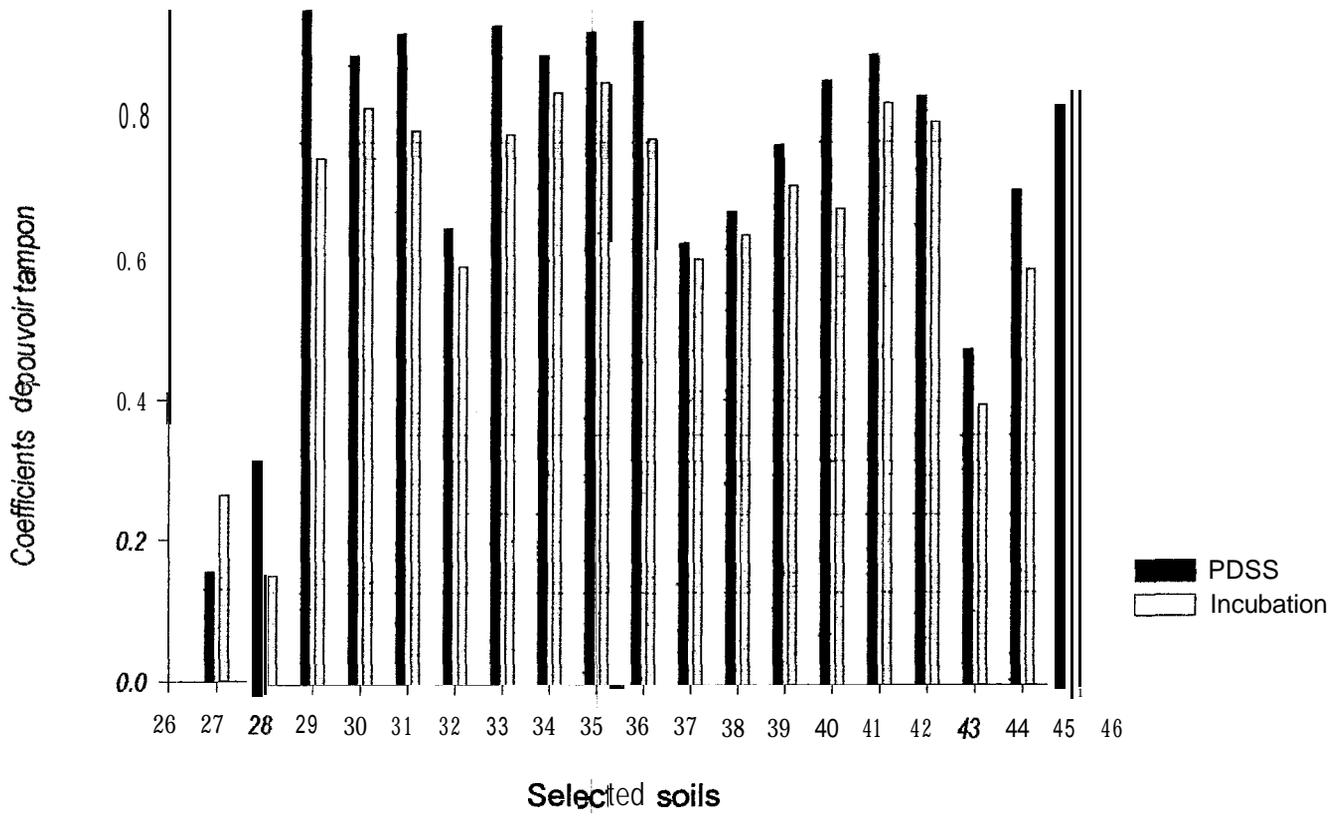
PBuffer7

Figure 7. P Buffer coefficient of selected soils of Niger

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Nutrient Balances Under Contrasting Millet Cropping Systems

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Abstract

On-farm research was conducted to estimate nutrient budgets under two cropping systems of Mali. These cropping systems included the sandy soils of Central Mali under permanent millet cropping system and the cotton cropping system of Southern Mali.

One farm was selected in one village of each of the selected areas. Dougouba, near Segou, was selected as the village for low input, millet cropping system while Dampela, near Koutiala, represented the 'high' input, cotton based cropping system. Partial nutrient balances were conducted in each farm. In each of these cases, soil samples were collected to estimate the initial nutrient status. Additions of nutrients were estimated by measuring application rates of soil amendments and performing laboratory analysis on samples of applied soil amendments. Nutrient exports were estimated by measuring biomass production and performing laboratory analysis on samples of the produced biomass.

Nutrient balances were negative under each cropping system: Dampéla: -21 kg N ha^{-1} , $-3,2 \text{ kg P ha}^{-1}$, $-9,1 \text{ kg K ha}^{-1}$; Dougouba: $-105.8 \text{ kg N ha}^{-1}$, -17 kg P ha^{-1} , -54 kg K ha^{-1} . The very low inherent fertility of sandy soils of Dougouba coupled to permanent millet cropping without any addition of mineral fertilizer is leading to a strong nutrient mining.

An implication of this study would be an integrated soil fertility management program aimed at soil fertility restoration and increasing farmers' income.

1. Background

Several research programs have provided evidence that soil fertility is indeed the number one factor limiting crop production in Central and Southern Mali and West Africa in general. (Stroosnijder, 1981; Doumbia et al., 1998; Breman et al., 1998). In fact, several constraints lead to soil fertility decline under cropping systems in Mali:

- The low inherent fertility and fragility of Malian soils (Poulain, 1976; Piéri, 1989; Wilding and Hossner, 1989; Traoré, 1974; Doumbia et al., 1993 and 1998),
- Application of very low rates of mineral and organic sources of plant nutrients (Piéri, 1989; Berckmoes et al., 1989; Van der Pol, 1992; Kieft et al., 1994),
- continuous removal of nutrients under traditional cropping systems (Van der Pol, 1992).
- constraints related to the use of the local, Tilemsi phosphate rock, PNT, (Kamara et al., 1994),
- disappearance or shortening of the fallow period (Hoefsloot et al., 1993),
- lack of crop residues management in traditional systems (Van der Pol, 1992),

- **cultivation** of marginal lands (Van der Pol et **Giraudy**, 1993),
- minimum or **lack** of **soil** conservation practices in traditional systems (**Kieft** et al., 1994).
- the need for **firewood** (**Kieft** et al., 1994),
- traditional pastoral systems (Van der **Pol**, 1992; **Kieft** et al., 1994),
- socio-economic conditions not favoring the use of chemical fertilizers (**Piéri**, 1989; **Kieft** et al., 1994).

Nutrients balances have been estimated for cropping systems of Mali as **well** as other countries of West **Africa**. (**Roose**, 1981; **Piéri**, 1983; **Duivenbooden**, 1990; Veldkamp et al., 1991; Van der **Pol**, 1992; Smaling et al., 1993 et 1996; Stoorvogel et al., 1993; Cretenet et al., 1994; Traoré, 1995). These **nutrient** balances are negative for N (-40 kg ha^{-1}), P (-2 kg ha^{-1}), K (-33 kg ha^{-1}), Ca (-8 kg ha^{-1}), Mg (-10 kg ha^{-1}), and CaCO_3 (-16 kg ha^{-1}) for the cotton cropping systems of Southern Mali (Van der Pol, 1992). A negative balance in N (-8 kg ha^{-1}), P (-1 kg ha^{-1}), et K (-7 kg ha^{-1}) was made for agricultural **soils** of Mali. This **nutrient** balance **will** be more negative in N (-11 kg ha^{-1}), P (-2 kg ha^{-1}), et K (-10 kg ha^{-1}) in year 2000 (Stoorvogel et al., 1993).

2. Objectives

The **general** objective of this study is to improve food security and environmental rehabilitation in **sandy areas** under permanent **millet** cropping systems.

The specific objective was to **estimate** partial **nutrient** balances under two **contrasting** cropping systems (on-farm) of Mali.

3. Materials and Methods

a. Sites Selection

Dougouba, near Segou, was **selected** as the village for “**low**” input, millet cropping system while **Dampela**, near Koutiala, represented the “**high**” input, cotton based cropping system. These villages were selected on the basis of their involvement in on-going IER (Institut D’Economie Rurale) activities. Selected characteristics of these villages are given in Table 1.

Tableau 1: Selected characteristics of the villages of Dougouba and Dampela.

Characteristics	Dougouba	Dampela
Families	32	44
Population	386	642
Farms	32	44
Average farm size (ha)	8	18
Area under cropping (ha)	261	792
Area under fallow (ha)	0	0
Communal pasture land (ha)	12	64
Collaborating NGO's or extension services	None	cotton company

b. Partial Nutrient Balances

One farmer was selected in each village. Mr. Lassine Djiré was selected from Dougouba and Mr. Bougoussama bembélé from Dampéla. Selected characteristics of these farms are given in Table 2.

A very simple approach, easy to explain to farmers, was adopted. Only N, P, and K nutrient additions (mineral and organic sources) and exports of nutrients (biomass of crops) were considered and estimated. Any other addition/export of nutrient was ignored.

Nutrient additions were estimated by first measuring applied quantities. Then samples were collected to determine their composition in N, P, and K (Sparks et al. 1996). Similarly, nutrient exports were estimated by first measuring the biomass produced (grain plus straw). Then samples were collected to determine their composition in N, P, and K.

Partial nutrient balances were made according to Van der Pol (1992), Van der Pol and Traoré (1993). However, as stated earlier the following simple formula was used: $B = A - E$; where B = partial nutrient balance, A = nutrient additions, and E = nutrient exports.

Table 2: Selected characteristics of the farms of Mr. Djiré (Dougouba) and Mi. Dembélé (Dampela).

Characteristics	Mi. L. Djiré (Dougouba)	Mr. B. Dembélé (Dampela)
Farmer class	C	A
Land ownership	Owens the land	Owens the land
Family size	6	27
Active members on the farm	2	23
Area under cropping (ha)	6	3 2
Soils (type: ha)	sandy: 6	loamy: 25 clayey: 3 bottom-land: 4
Crop rotation	Millet-millet	Cotton-maize
Crops: No. of fields	Millet/cowpea: 2 Groundnut: 2 Fonio: 1 Vouandzou: 1 Cassava: 1	Cotton: 3 Rice: 7 Sorghum: 3 Millet: 9 Maize/cowpea: 1
Cattle	0	33
	4	15
Goats S&E	2	4
Donkey/horse	2	1
Chicken	7	30
Cart	1	1
Plow	1	2
Weeder	0	2
Seeder	0	1
Use of harvest	Food	Food/Sale
Use of crop residues	Feed/compost	Feed/compost
Organic sources of nutrients used	8000 kg manure	7500 kg manure 12000 kg wastes
Mineral fertilizers used		850 kg urea 600 kg Cco* 400 kg Cce*
Other inputs (purchased)	None	Cotton seed Insecticide: 12 L

* Cco is a Cotton fertilizer blend (14-22-1 2-8S-1.5B), Cce is a cereal fertilizer blend (15-15-15)

4. Results and Discussion

Selected characteristics of the villages and farms were given in Tables 1 and 2. Dougouba receives a **mean annual rainfall** of 600 mm (Sivakumar et al., 1984). This village is located in the “**Albida Parkland**” (*Acacia albida*), characterized by deep **sandy soils**. Dampela receives a **mean annual rainfall** of 800 mm (Sivakumar et al., 1984). This village is located in the “**Old Cotton Belt**”, where cotton **cultivation** is the oldest in the country. In addition, Dampela has a **strong comparative advantage over** Dougouba: the cotton company **provides** on a **loan basis**, all the **inputs** required.

Additions and exports of nutrients (N, P et K) to/from the farms Mr. Dembélé (Dampela) and Mr. Djiré (Dougouba) are indicated in the tables, 3 through 8.

Table 3. Mr. Dembélé (Dampela) farm: nutrient additions by mineral and organic sources.

Additions (Crop: fertilizer)	N (kg)	P (kg)	K (kg)
Millet B1: Urea	23		
Cotton B2: Manure	181.7	25.2	135.5
Cotton B2: CCo	28	44	24
Cotton B2: Urea	46		
Millet B3: Urea	25.3		
Millet B4: Urea	23		
Millet B5: Urea	20.7		
Cotton B6: Manure	77.9	10.8	58.1
cotton B6: CCo	21	33	18
Cotton B6: Urea	23		
Maize B7: Urea	23		
Maize B7: Cce	15	6.6	12.5
cotton B8: Cco	21	33	18
Cotton B8: Urea	23		
Sorghum B9: Urea	23		
Sorghum B9: Cce	7.5	3.3	6.2
Sorghum B12: Urea	46		
Sorghum B12: CCe	7.5	3.3	6.2
Sorghum B13: Urea	23		
Sorghum B13: CCe	7.5	3.3	6.2
Cowpea B15: Urea	4.6		
Voandzou B16: Urea	2.3		
Sorghum B23: Urea	46		
Sorghum B23: CCe	15	6.6	12.5
TOTAL	734	169.1	297.2

Table 4. Mr. Djiré (Dougouba) farm: nutrient additions by organic sources.

Crop (Crop: fertilizer)	N (kg)	P (kg)	K (kg)
Millet D1: Manure	26.0	3.6	19.4
Millet D3: Manure	34.6	4.8	25.8
Millet D5: Manure	8.7	1.2	6.5
TOTAL	69.3	9.6	51.7

Table 5. Mr. Dembélé (Dampela) farm: nutrient exports by crops.

Crop (Crop: fertilizer)	N (kg)	P (kg)	K (kg)
Millet B1	66.7	15.4	31.9
Cotton B2	139.6	26.0	52.0
Millet B3	82.2	19.0	39.4
Millet B4	111.2	25.7	53.2
Millet B5	63.6	14.7	32.1
Cotton B6	230.1	42.8	85.7
Maize B7	47.2	9.6	33.6
Cotton B8	21.9	22.7	45.4
Sorghum 9	123.7	20.9	25.9
Groundnut B10	1.4	0.1	0.5
Rice B11	7.7	1.7	9.0
Sorghum B12	40.0	6.8	8.4
Sorghum B13	1.5	3.1	3.9
Groundnut B14	5.1	0.4	2.0
Cowpea B15	0.6	0.2	1.0
Voandzou B16	1.5	0.1	0.6
Rice B17	9.9	2.2	11.7
Rice B18	8.6	1.9	10.2
Rice B19	17.8	3.9	20.9
Rice B20	12.3	2.7	14.4
Rice B21	9.9	2.2	11.6
Rice B22	36.6	8.1	43.2
Sorghum B23	251.1	12.5	52.4
TOTAL	1407.2	272.7	589.0

Table 6. Mr. Djiré (Dougouba) farm: **nutrient** exports by **crops**.

Crop (Crop: Code)	N (kg)	P (kg)	K (kg)
Millet D1	120	26.4	57.6
Cowpea D1	12	3.6	27.8
Groundnut D2	102	7.9	38.4
Millet D3	160	35.2	76.8
Fonio D4	9	1.9	4.8
Groundnut D5	102	7.9	38.4
Millet D5	40	8.8	19.2
Cassava D6	57	11.4	73.6
Voandzou D7	102	8.2	38.8
TOTAL	704	111.3	375.4

Table 7. Mr. Dembéle (Dampela) Farm: partial **nutrient** balance.

Addition/Export	N (kg)	P (kg)	K (kg)
Additions	734	169.1	297.2
Exports	1407.2	272.7	589.0
Balance	-673.2	-103.6	-291.8

Table 8. Mr. Djiré (Dougouba) Farm: partial **nutrient** balance.

Addition/Export	N (kg)	P (kg)	K (kg)
Additions	69.3	9.6	51.7
Exports	704.0	111.3	375.4
Balance	-634.9	-101.7	-323.7

Tables 7 and 8 show that **nutrient** balances are **negative** for N, P and K, at both locations, Dampéla and Dougouba. In addition, these **nutrient** balances indicate **soil mining** in the **following** rates:

Dampéla:	-21 kg N/ha	Dougouba	-105.8 kg N/ha
	-3.2 kg P/ha		-17 kg P/ha
	-9.1 kg K/ha		-54 kg K/ha

By **comparison**, Van der Pol (1992) and Van der Pol et Traoré (1993) reported the **following** mean values for **nutrient** balances for **cotton** based cropping **systems** of Southern Mali:

- 25 kg N/ha
- 0 kg P/ha
- 20 kg K/ha

5. Conclusions and Perspectives

a. Conclusions

Complete **nutrient** balances are **difficult** to measure. The **nutrient** balances were negative under **each** cropping system: **Dampéla**: -21 kg N ha⁻¹, -3,2 kg P ha⁻¹-9,1 kg K ha⁻¹; **Dougouba**: -105.8 kg N ha⁻¹, -17 kg kg P ha⁻¹, -54 kg K ha⁻¹. **One** of the main constraints in **Dampéla** is the **lack** of arable land, **thus resulting** in a higher **input** cropping system, especially **using** chemical **fertilizer** on cereal **crops despite very** low ratios of **product** prices to **input** prices (**Kelly et al., 1998**). This high **input** cropping system is **supported** by the **cotton company**, by **making both credit and inputs available to farmers of Dampéla. Even with these "high" inputs the soils are being mined.** Nevertheless, the lower **inherent** soil **fertility** at **Dougouba** and permanent millet cropping with application of **lower** rate of **nutrient input** resulted in an even more negative **nutrient** balance.

b. Perspectives

One of the objectives of **this** research was to develop an integrated soil fertility management program **aimed** at **improving** the negative **nutrient** balances. The **following** activities are suggested to reduce the negative **nutrient** balance at **each** site.

- Addition of Tilemsi phosphate rock **during** composting. This would not **only** improve the P balance, but also **alleviate several** of the **constraints** reported by Kamara et al. (1994).
- **Phosphorus** recapitalization (**using** Tilemsi phosphate rock) to **alleviate P deficiencies** and improve P balance of **these soils** (Poulain, 1976; **Piéri**, 1989; Doumbia et al., 1998; **Sanchez et Izac**, 1995).
- Early **planting** to capture N **flushes** at the on-set of the rainy season (Birch, 1964).
- More integration of legumes in the cropping system.

In addition, at **Dampéla**, there is a need **to** increase the efficiency of use of chemical **fertilizers, especially** when applied to cereal. An efficiency of 20 kg **millet/sorghum** grains per kg of **fertilizer is required** to achieve a **value/cost** ratio of 4 (**Kelly et al., 1998**).

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THEME 4 :ENVIRONMENTAL IMPACT

Drinking Water Quality as Influenced by the Cropping System

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Abstract

Water samples were collected from wells in two villages located in two contrasted agricultural zones of Mali to assess the impact of cropping systems (inputs) on the quality of drinking water. The first village, Dougouba, is located on sandy soils under permanent millet cropping system. The second village, Dampela, is located in Southern Mali, on loamy soils under very intensive cotton cropping system. Collected water samples were analyzed for pH, N, P, Ca, Mg, K, and Na.

Concentrations of P, Ca and Mg were low as 0.04 mg P L⁻¹, 0.02 mg Ca L⁻¹, and 0.01 mg Mg L⁻¹. High variations were found in the concentration of mineral N (0.25 to 1.00 mg L⁻¹), K (12.5 to 200 mg L⁻¹), Na (5 to 40 mg L⁻¹), and the values of pH (5.5 to 7.5). Higher concentrations of N were found in water samples from Dampela. Higher concentrations of K and Na were found in the sample from the sandy soils of Dougouba.

The data presented here are just preliminary assessments. More literature review and research are needed to validate these data.

1. Background

The low inherent fertility and fragility of Malian soils (Wilding and Hossner 1989; Doumbia et al., 1993, 1998) coupled with factors such as erratic rainfall, continuous removal of nutrients under traditional cropping systems, lack of crop residue management in traditional systems, cultivation of marginal lands, minimum or lack of soil conservation practices in traditional systems, the needs for firewood, and traditional pastoral systems have resulted in soil degradation and yield reductions (Van der Pol, 1992; Kieft et al., 1994).

Despite the above constraints cotton yield in the cotton cropping system of Southern Mali has gone from 200 Kg ha⁻¹ (early 1960's) to 1300 Kg ha⁻¹ (Traore, 1995). Yield projections of 1500 – 2500 Kg ha⁻¹ have been made. These yield increases are due to the use of variable rates of chemical fertilizers (200 Kg ha⁻¹), organic sources of nutrients (1 – 5 Mg ha⁻¹), herbicides (1 – 3 L ha⁻¹) and insecticides (6 – 12 L ha⁻¹). After more than 30 years of cropping practices involving the above inputs, very limited information is available on their impact on the environment. This research attempts to initiate an environmental impact assessment study of these cropping systems on groundwater quality.

2. Objectives

The general objective of this **research** was to assess the impact of cropping systems on the environment. The **specific** objective was to assess the impact of inputs on the quality of drinking water (**from Wells**).

3. Materials and Methods

Villages were selected **from contrasting agricultural zones**. The **first** village, Dougouba, is located in Central Mali, **in sandy soils** under permanent millet cropping **system**. Farmers of this village use **several sources** of manure, but use neither chemical fertilizers nor **pesticides**. The second village, **Dampela**, is located in Southern Mali, on loamy soils under **very intensive cotton cropping system**. Farmers of this village use not **only** high rates of manure and chemical fertilizers, but **also** several treatments of insecticides and herbicides.

Families selected (25) at Dougouba for the **baseline** evaluation of the Soil Management CRSP were retained for **this** study. That evaluation collects socio-economic and **cropping** strategies data on these **farmers**. At **Dampela**, 25 families were also selected on the basis of their participation in on-going **survey** of cropping systems.

Water samples were **collected from wells** (in September, when most of the chemical inputs have assumedly reacted), using local materials traditionally used.

Collected water were analyzed for pH, N, P, Ca, Mg, **K**, and Na according to **procedures suggested** by Sparks et al. (~1996).

4. Results and Discussions

Concentrations of P, Ca and Mg were **very low**, within and **across** villages. These concentrations were as low as 0.04 mg L⁻¹ for P, 0.02 mg L⁻¹ for Ca and 0.01 mg L⁻¹ for Mg. These values **need** to be **compared** to threshold concentrations.

Concentrations of mineral N are presented in Figure 1. These frequency histograms show high variations in the **concentration** of mineral N in drinking water samples (0.25 to 1.00 mg L⁻¹). Higher concentrations of mineral N are **shown** for the **samples from Dampela**, the site under intense cotton **production**. None of the nitrate levels are dangerously high at the moment.

Concentrations of K are presented in Figure 2. Here **again**, these frequency histograms show high variations in the **concentration** of K in drinking water samples (12.5 to 200 mg L⁻¹). **Higher** concentrations of K are **shown** for the **samples from Dougouba**, the site with **sandy soils** under permanent millet cropping systems. These higher rates **may** be due to **leaching of K from manure applications** (the only input used in the cropping system beside seeds).

Concentrations of Na are presented in Figure 3. Here **also**, these frequency histograms show high variations in the **concentration** of Na in drinking water samples (5 to 40 mg L⁻¹). Higher concentrations of Na are shown for the **samples from Dougouba**. These higher concentrations **may** be due to the impacts of household activities **carried out near**

wells.

The pH of **collected** water samples are presented in Figure 4. Here also, these **frequency** histograms show high variations in the pH of drinking water samples (5.5 to 7.5). Higher pH values are **shown** for the **samples** fi-om Dougouba. These pH values cor-relate **well** with the higher concentrations of Na **reported** for **these** samples (Figure 3).

5. Conclusions and Perspectives

Conclusions

Concentrations of P, Ca and Mg were low as 0.04 mg P L⁻¹, 0.02 mg Ca L⁻¹, and 0.01 mg Mg L⁻¹. **High** variations were found in the concentration of **mineral** N (0.25 to 1 .00 mg L⁻¹), K (12.5 to 200 mg L⁻¹), Na (5 to 40 mg L⁻¹), and the values of pH (5.5 to 7.5).

Higher concentrations of N **were** found in water samples from the loamy **soils** of **Dampela under** intensive **cotton** cropping **system**. Higher concentrations of K and Na were fong in the **sample** from the **sandy soils** of Dougouba where the use of **manure** is probably higher.

The data presented here are **just** preliminary assessments. Data have **yet** to be found En order to compare the concentrations **of the** above elements to threshold values.

Perspectives

There is a need for **further analysis** of the data or collection of more data to explain the high variability found not only **within** samples **from** the **same** village, but **also** between samples **from** the two villages.

Future works on this **activity will** be implemented in the **same** villages, but thorough sampling in **each** household **may** be **desirable** for better **understanding**. The use of a tool **such** GPS **may help** in both the data collection process and the trends in concentrations.

Thorough **analysis** of the water **sample** is also desirable. In **fact**, components **such** as **heavy** metals and biological activities are important in **evaluating** the impacts of cropping **systems** on the **environment**, **especially** the quality of drinking water.

There is also a need for methods for laboratory **analysis** of the samples. A literature review will be requested **from** our collaborators at the University of Hawaii on this issue.

WQual1

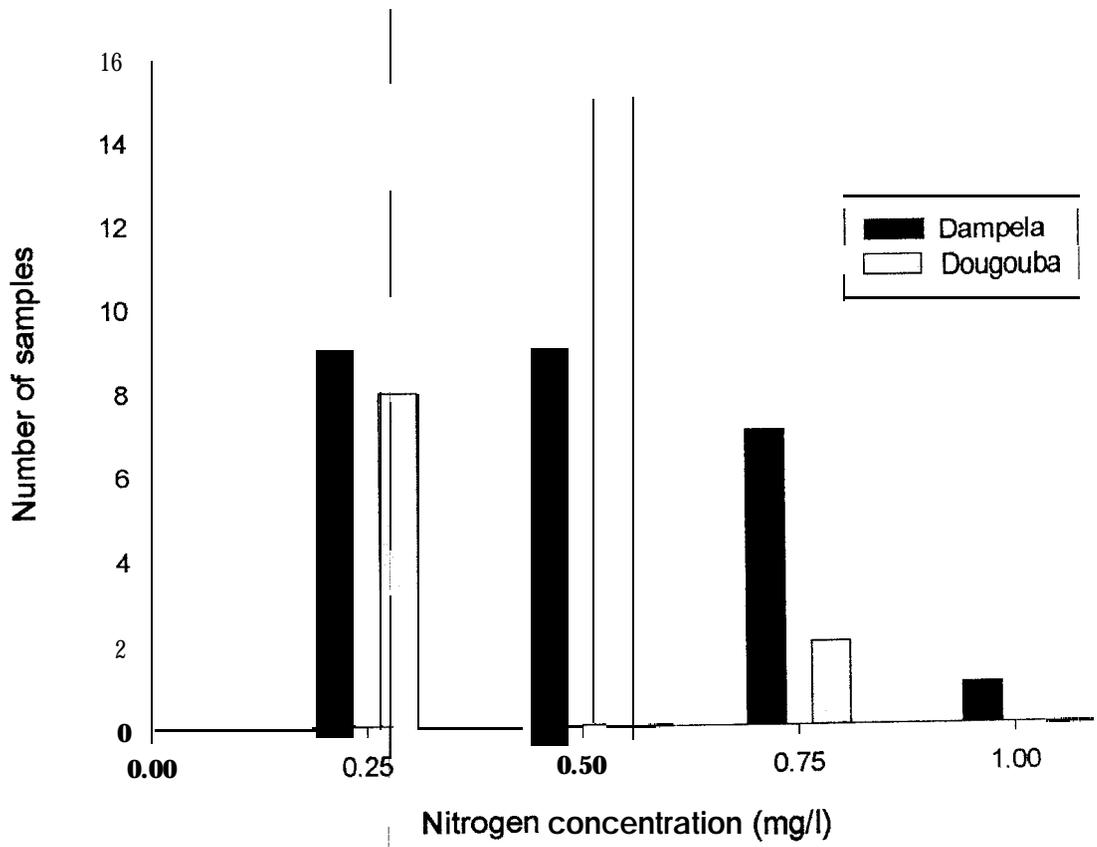


Figure 1. Frequency histogram of N concentration in wells

WQual2

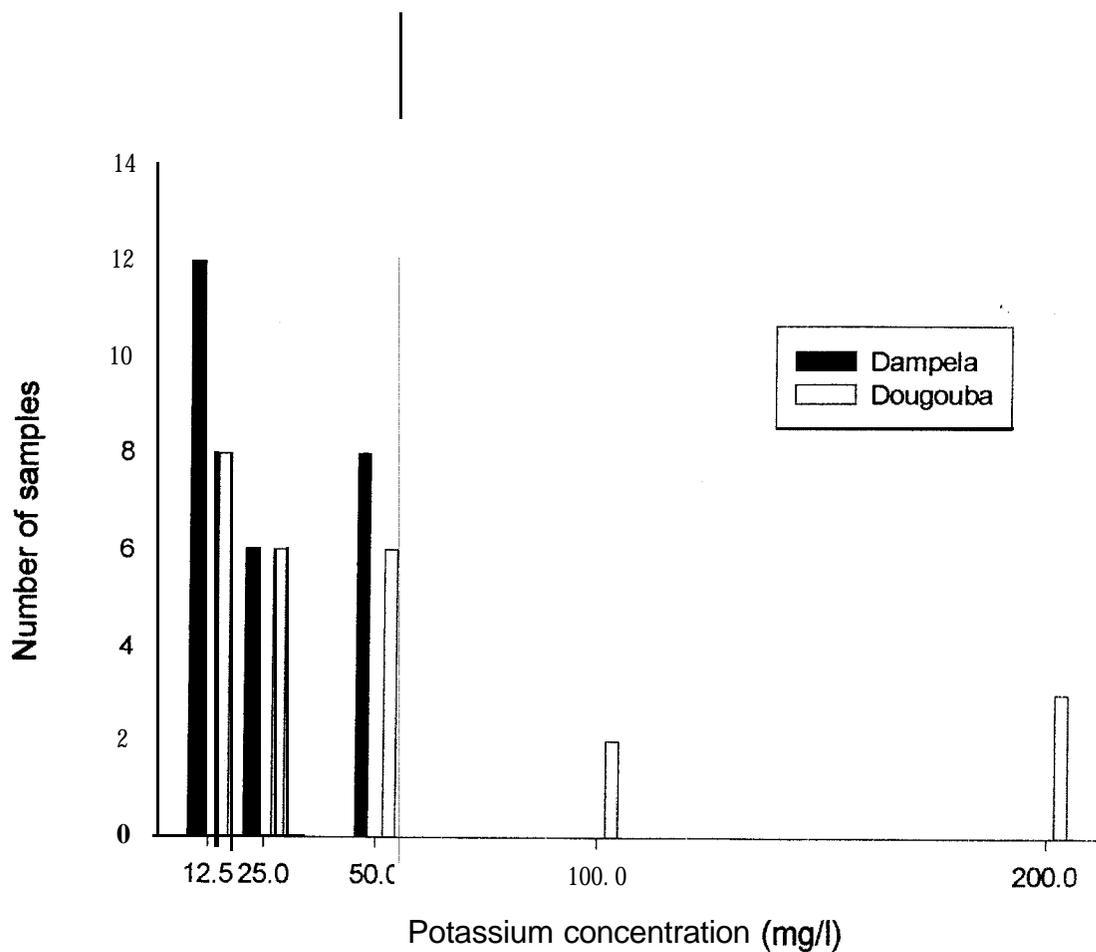


Figure 2. Frequency histogram of K concentration in wells

WQual3

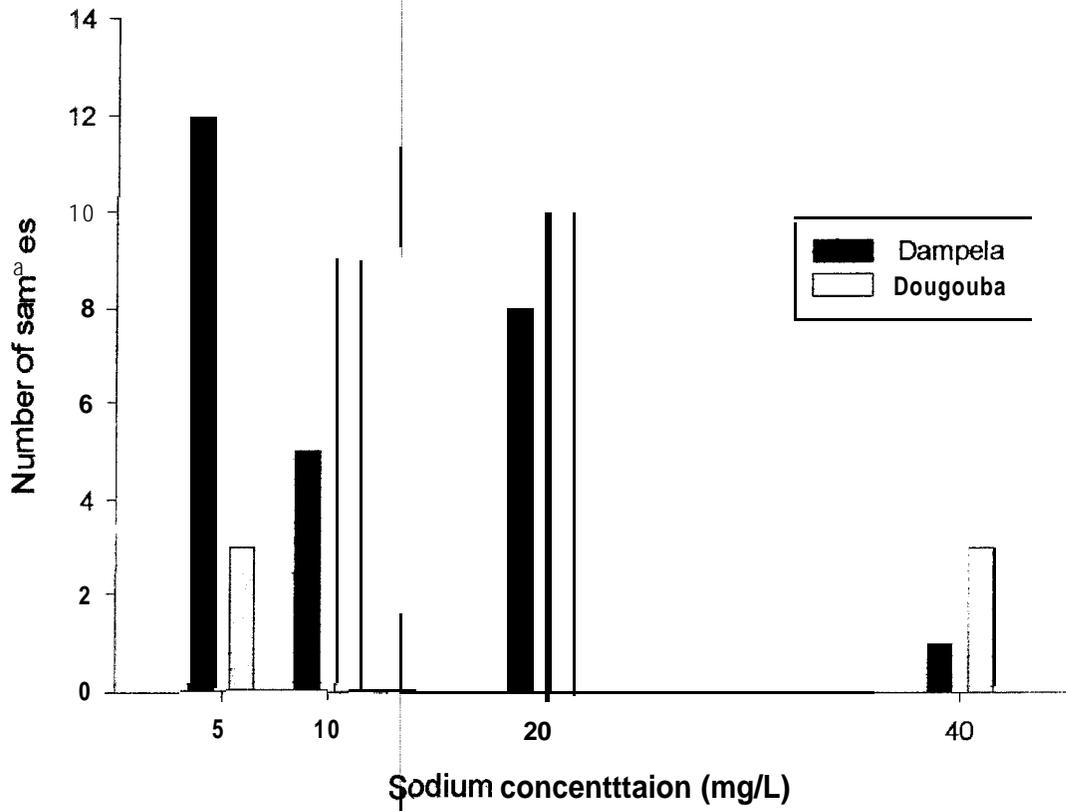


Figure 3. Frequency histogram of Na concentration in wells

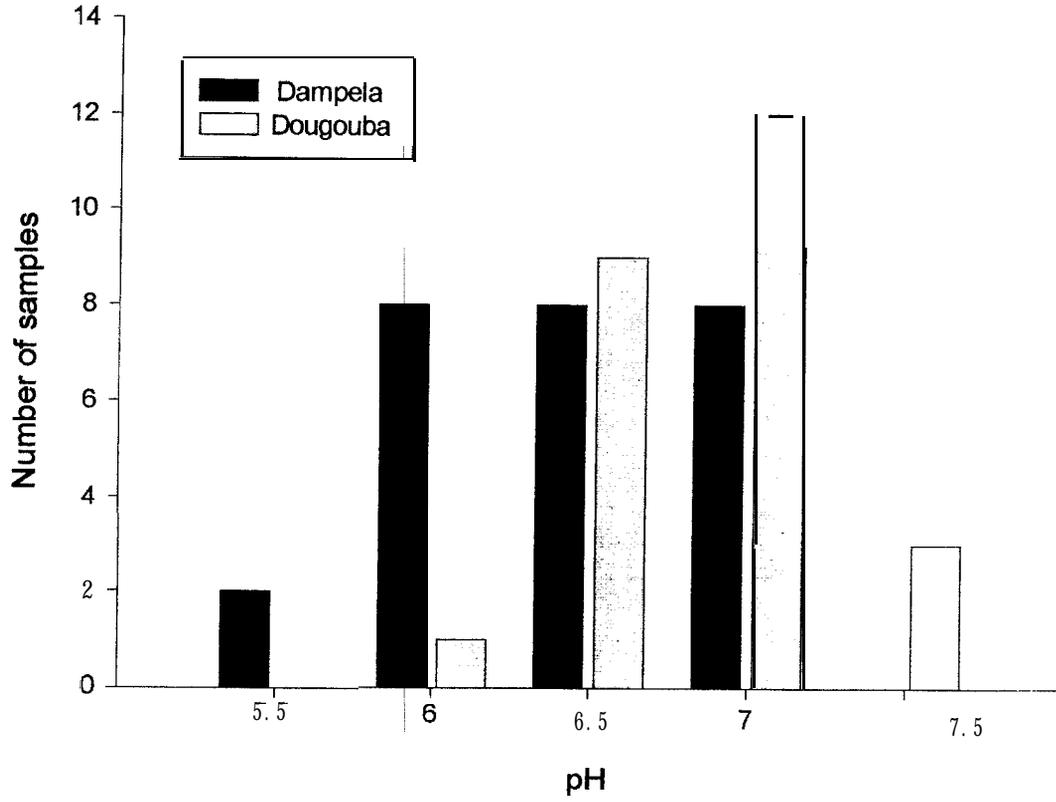
WQual4

Figure 4. Frequency histogram of the pH of wells waters

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ANNEXES

Report of the Field trip to the Koutango and Nioro Sites

M. Diack, ISRA Senegal

As part of the workshop program, the field trip gave an opportunity to the participants to visit the Koutango and Nioro sites where the InterCRSP experimental plots were located.

7H 30 am

The visitors left Kaolack for the Koutango site, 69 km, South-west from Kaolack.

9H 05 am

They arrived at the site and were introduced to Mr. Mansour Dème, field worker and owner of the field by Dr. Modou Sène. A nutrient management program is being carried out on rice under rainfed. Rock phosphate and phosphogypsum as P and Ca sources and manure are the fertilizer forms used in the experiment (see papers).

Several questions about the perception that farmers have on the phosphogypsum program, initiated by the Government of Senegal, were asked.

Was the phosphogypsum efficient as fertilizer?

Yes, and I am also using it to control salinity, replied Mr. Dème.

What if the Government stopped providing fertilizer freely?

I will purchase it, he said.

Beside rice, Mr. Dème grows vegetables because water is available.

The site is within an interesting valley for which ISRA intends to run a research and development program under lowland conditions. Dr. Diack, coordinator of that program, presented preliminary data obtained from both socio-economic and hydrologic surveys conducted in the valley. The data showed a great agricultural potential of the valley. However, soil constraints such as salinization, acidity and water management need to be addressed. From the socio-economic standpoint, villages established around the valley are organized into 57 groups based on economic interest. The R and D program will be carried out by a multidisciplinary team composed of scientists from ISRA, the University of Dakar and an NGO.

9H 45 am.

The participants left Koutango for the Nioro Research Station, second site

11H 45 am.

As they arrived at the Research Station, the participants were introduced to the local staff by Dr. Modou Sène. The visit started with experimental plots among which the *Piliostigma reticulatum* trial under peanut/millet rotation, a second trial where rock phosphate and phosphogypsum as P and Ca sources and manure were compared under a peanut/millet rotation and a third experiment combining nutrient management and water balance (see papers). The participants also visited the small dam implemented to control runoff/erosion in the watershed.

For each trial, several questions were asked, leading to important discussion.

From the discussion, one could appreciate the amount of work done so far, meaning the InterCRSP program in Senegal is going well.

1H 20 pm

The participants left Nioro for Kaolack.

2H 15 pm. Arrival at Kaolack.

The following participants took part to the field trip:

1. **Russel YOST**
2. **Gaoussou TRAORE**
3. **Samuel BRUCE-OLIVER**
4. Aminata **SIDIBE**
5. **Isuarina BAPTISTA**
6. **Aminata BADIANE**
7. Abou **BERTHE**
8. **Mamadou DOUMBIA**
9. **Kevin BRANNAN**
10. Richard **KABLA**,
11. **Mouhamed KEBBEH**
12. Babou **JOBE**
13. **Cheikh NDIAYE**
14. Modou **SENE**
15. **Mateugue DIACK**

REPORTS ON SESSIONS

Report for themes 1 and 2

Monday, January 11, 99

Chairman: Dr. Jean Pierre N'DIAYE

Secretary: Ms. Aminata SIDIBE

The themes **discussed** below were **preceded** by keynote addresses **from Dr. Gaoussou Traore**, Head of Division at **INSAH**, and Dr. Russell S. Yost, Coordinator of the West InterCRSP Group.

Dr. Traore gave an overview of the **activities** and strategic workplan of MSAH. He indicated that **InterCRSP** is a **program** falling into the **natural resource** management program of **INSAH**. He **insisted** that **InterCRSP** should work under the umbrella, and **should** therefore keep **INSAH** **updated** on anything **regarding** this collaborative research program. Discussions related to this speech were on information **procedures** between the **West** InterCRSP Group and **INSAH**, the ROSELT program, and interactions **with** other CRSP.

Dr. **Yost** gave an overview of activities of the **West InterCRSP** Group. He recalled the overall objective of the program: **natural resources management** for food security and **income**. As a justification of this objective, he **pointed out that** food supply decreased by 18% in the target **area** of the **West** InterCRSP. There is an urgent need to reverse the factors **contributing** to this **decline** in production. Dr. Yost **illustrated** by a slide show some of these factors in **each** of the 4 countries of the West InterCRSP group. **These factors include: loss of soil organic matter, nutrient** depletion, soil acidification, **soil loss** by **erosion, erratic rainfall**, degradation of natural resources, etc... These factors were grouped into 4 major themes for the workplan: (i) Farm programming and **policy**, (ii) Soil and water conservation, (iii) **nutrient** management, and (iv) environmental impact. Discussions related to this **presentation** were **about** localized manure application at Dougouba (Mali), spatial variability in a sorghum field at Fansirakoro (Mali), **salt** intrusion in **Senegal** and The Gambia, and **erosion** control on hill **slopes** of Cape **Verde**.

Theme 1: Farm Programming and Country Policy

Country presentations under this theme were made for Cape Verde, The Gambia, and Mali.

Cape Verde: Farmer to Farmer Visit by Isaurinda Baptista and Isabel Anahory

In Cape Verde, soil characteristics, **topography** conditions and **climate** constraints have produced a unique agricultural **system**. Major **constraints** to this **agricultural system** are **salinity**, loss of **soil organic matter**, and **soil** erosion. Inter farmer visits were organized to exchange **views** on techniques **used** by farmers to alleviate these **constraints**. These visits in **different areas** were **successful** and farmers **suggested** that this type of **activity** is worth **repeating**.

Discussions related this presentation were on soil types, drip irrigation, soil erosion measurements, and the benefit farmers get from interacting among themselves. It was recommended to increase the frequency of these "farmer-to-farmer" visits.

The Gambia: Adoption and Farm Level Impact of Improved Fertility Management Technologies in the Sudano-Sahelian Zone of The Gambia by Mohamed Kebbeh

Low inherent soil fertility and decreasing levels of chemical fertilizer use have partly explained the significant decline in crop yields in Gambian uplands. Researchers are attempting to address this problem by evaluating alternative soil fertility management strategies in eastern and western Gambia. Whole farm models are developed to assess the adoption and farm level impacts of combinations of organic and inorganic fertilizers. The results of the simulations show positive response to chemical fertilizer price changes. For example, area under millet would increase drastically, at the expense of groundnut and maize, with a 25% decrease in chemical fertilizer prices.

Discussions related this presentation were on The use of value/cost ratio in comparison with the model described in the presentation and the relevance of changes in the prices of fertilizers. Such a change of 25% decrease was thought unlikely as chances for fertilizer subsidy or tax cut on fertilizers are very slim. It was suggested to address issues such that: (i) who will adopt the technology? (ii) what will be adopted? (iii) what proportion of the technology? (iv) how sustainable is the technology? In addition, it was suggested to conduct this type of evaluation in each country of the West InterCRSP group.

Mali: Improving and Sustaining Food and Raw Material Production in West Africa: A Participative Rapid Rural Appraisal in Fansirakoro by Russell S. Yost and Abou Berthe

A participatory rapid rural appraisal (PRRA) was conducted to provide a baseline information on the farming systems found in the area of Kati (Mali) in order to establish research priorities for the InterCRSP project. According to farmers, yield decline was due to diminishing rainfall, lack of moisture, reduction of the density of trees, reduction of organic matter in the soil, and increased mn-off. It was concluded that the main agricultural production constraints are related to soil and water conservation and management. Recommendations to alleviate the above constraints were divided into 2 recommendation domains, one representing 30% of the farmers and the other representing 70% of the farmers (very resource-poor farmers).

Discussions related this presentation were on the lack of information on organic fertilizer production, the method used to conduct the PRRA, the definition of recommendation domains, and steep hillside farming in the area.

Theme 2: Soil and Water Conservation

Country presentations under this theme were made for Mali and Senegal.

Mali: Improving Food Production in Subsistence Farming Systems in Fansirakoro and N, Tentoukoro by A. H. Berthe, S. F. Traore, B. Traore, C. D. Kamissoko, B. Guindo, R A. Kablan, and R S. Yost.

An on-farm trial involving 10 farmers in both villages of Fansirakoro and N, Tentoukoro was conducted to evaluate the effect of different fertilizer management systems on the productivity of sorghum. Ear and grain yields were not statistically different. Farmers ranked the treatments, according to visual assessment, the combined manure/fertilizer first, the manure second, and the check last.

Discussions related this presentation were on a yield increase of 400 kg of sorghum grain per ha, the treatments of the experiment, the variability and the significance of some of the data collected.

Senegal: Effect of Manure and P-Source Fertilizer on Water and Nutrient Use for Main Crops in Senegal Peanut Basin by M. Sene, M. Diack, and A. Badiane.

A long term experiment was initiated to evaluate the effects of several combinations of phosphate rock and phospho-gypsum on water and nutrient use for several crop in the Peanut Basin of Senegal. This experiment is going on for the second year. The data generated so far show little impact of the treatments due to the low solubility of the Taiba phosphate rock and the limited nutritive value of the phospho-gypsum (it is however rich in calcium and sulfur).

Discussions related this presentation were on the relevance of long term experiment on this InterCRSP project which "quick-results-to-the-farmer" oriented, soil properties, and phospho-gypsum issues.

Tuesday, January 12, 99

Presentations of Session 3: Nutrient Management

Cape Verde Isaurinda Baptista

Effect of Organic and Inorganic Fertilizers on: the nutrient status and yield of dry land crops (maize and beans)

Objectives : 1) to evaluate the effect of both chemical fertilizer and animal manure on crop growth and yield ;
2) to improve soil conditions both physically and chemically.

Conclusion :

The trial was not followed to the end because of crop failure due to drought.

However, the manure plus fertilizer **out-performed** other treatments with the highest dry **matter** yield of 3.92 **Mg/ha** compared to 2.27 **Mg/ha** for the control. It was suggested to continue the **study** under favorable moisture conditions **so** as to **meet** the objectives.

Discussion

Question 1 : Why was it that **you apply** organic fertilizer ? **Is** the soil degraded ?

Answer : We were interested in the long-term **effect**, but the soil at the site **is** not degraded.

Question 2 : Why did **you** apply 20 **t/ha** of manure ?

Answer : **It** is the rate that is recommended.

Question 3 : How was the manure **handled** ?

Answer : There **is** no **special** management. It was just **collected from** pens and transported to the field for application.

Question 4 : **Is** there **any** marketing on manure ?

Answer : No, but we brought the **material** for our trial **from** a farm.

Question 5 : There appears to be **inconsistency** in the measured values from organic **matter** for the control ?

Answer : **Yes**, I've realized the **inconsistency**. Hope to look at it **again**.

Question 6 : Why cow manure per se ?

Answer : Cow is most commonly **used**, but poultry manure is also available but not used on large because it bums the **crops**.

2. Mali : Aminata Sidibé

Phosphorus Buffer Coefficients of Selected Soils of West Africa

Objective : To **validate** P buffer **coefficients** predicted by the Phosphorus **Decision** Support System (PDSS) model.

Conclusion : P **buffer** coefficients **determined** fi-om the model were not **significantly different** fi-om those of the incubation **studies**. However, the **clay soils** tend to have lower coefficients with the incubation method. Further study is needed to investigate this **effect**.

Discussion

Question 1: What type of **clay mineralogy** are your soils ?

Answer : Mostly kaolinite (1: 1) **clays**.

Supplement : Upland soils in Mali have fixation of 12 **g/kg** and the Smectites of the lowlands **fix** at the rate of 150 **g/kg**.

Question 2 : Did **you** analyze for **clay mineralogy** ?

Answer : No, we do not have the **capacity**. However, we **can always** send it to the other labs for X-ray diffraction.

Mali : Mamadou Doumbia

Nutrient Balances under Contrasting Millet Cropping Systems

Objective : to **estimate** nutrient budgets under three millet cropping systems in Mali.

Conclusion : All three cropping systems registered negative nutrients balance but it was highest under the **cotton based** cropping systems.

Discussion :

Question 1 : **What is your present strategy for soil fertility restoration ?**

Answer : No particular **one** as yet **because** we are **just** starting. However, we are **currently** looking **into** composting **with** rock phosphate, chemical **fertilizer** and improved **manure** storage.

Question 2 : **How do you account for soil input ?**

Answer : There are **different approaches** :

- 1) **Input** as **amendment** - **output** (crop removal)
- 2) **Initial** level + addition - **output**.

Question 3 : **Do you have a methodology you can use ? I want to do a similar study in Cape Verde ?**

Answer : As I said, there are **different approaches**. You use the method most appropriate **to your** conditions. We **will** however **talk** more.

Question 4 : **What would you recommend ?**

Answer : We are not **yet** ready **with** the data. We have **to** look **at** it **again** and if funds are available, we **will** continue **the work**.

Senegal : Mateugue Diack

Use of *Piliostigma reticulatum* (local shrub) to improve upland soil conditions in a millet/groundnut rotation system.

Objective : To evaluate the influence of *Piliostigma reticulatum* on the soil quality and crop yield.

Conclusion : Trial **implementation** in process. **Results** obtained so far suggested **decomposition** of plant parts **to be faster** under field **than laboratory** incubation conditions. It was either **that soil microbes** were excluded from soil **during sample** preparation for **laboratory incubation** or the soils are **biologically degraded**.

Discussion

Question 1 : **Why was millet yields too low ?**

Answer : **The millet crop** was lately **planted** coinciding **with** dry spell.

Question 2 : **What was the methodology for N analysis during laboratory incubation ?**

Answer : We used **the classical method**, but **one** has **to do it fast** under optimum temperature.

Question 3 : **How can animal traction be adapted in managing the residues of this shrub ?**

Answer : Animal traction is not an **obstacle** in the management of shrub residue especially **at weeding** when the re-growth is tender **and gets incorporated** readily for faster decomposition.

Senegal : Modou Sène

Use of Phosphogypsum (PG) to correct P deficiency

Objective : **to evaluate PG against Rock Phosphate**

Conclusion : **No response** by com in the first year.. For second year, **groundnut pod** yield was most significantly increased by **lime alone treatment** followed by treatment combinations **containing more by ratio** of PG than RP.

Discussion

Question 1 : **What liming material did you use ?**

Answer : Calcium oxide (**CaO**) at **400 kg/ha**.

Question 2 : Are there **several** forms of PG ?

Answer : There are **different** types of RP but PG is a by-product of RP.

Question 3 : What is the variability in PG ?

Answer : **I cannot tell you** now. We are **still** working on the data.

Comment : **PG sent to Mali contains 1% P₂O₅ and 38% CaO.**

Question 4 : Did **you** assess PG on biological N **fixation**.

Answer : No.

Comment : A work with RP which had positive **effect** on **LR** was recalled.

Question 5 : What was your initial **soil** exchangeable calcium test ?

Answer : 0.6 **meq/100 g** of **soil** and **rose** to 0.8 **after amendment**.

Comment : **That may explain** the **superiority** of lime and PG in increasing pod yield.

Groundnuts will likely respond to **calcium** in **soil** with less than 1 .0 meq/100 g of exchangeable calcium

Mali : Mamadou Doumbia**Environmental Impact Assessment Study**

Objective : to assess the impact **different** cropping practices have on the quality of **well** water.

Conclusion : Minimal levels of nitrate **and** phosphorus detected but elevated levels of potassium and sodium were tested in water.

Discussion :

Suggestion on methodology for **such assessment** were invited.

Comments :

1. **You** need to measure electrical **conductivity** (EC)
2. There **is** a threshold value for P **for lake** eutrication but not for **drinking** water
3. **Identify** proximity of locations to **wells** where **human activity** are possible source for contamination
4. **Group wells** by locations.

The Gambia : Babou Jobe**An Integrated Fertilization Study of the Groundnut/millet rotation system of North Bank Division**

Objective : 1) to assess changes in **crop** response (biological and economic yields) due to **different soil amendments**

2) to assess changes in **soil properties** due to **different soil** amendments.

Conclusion : Regardless of the type of manure, manure plus fertilizer influence crop yield and soil properties more **positively** than **fertilizer** alone. To **manage** fertilizer well for reasons of **cost** and environmental integrity, it's **best** to explore the complementary effects of **manure plus fertilizer**. There is also a need to improve on the transportation

and field handling of manure in promoting **large-scale** adoption of manure use for field **crops**

Discussion :

Question 1 : Was this a station or **on-farm** experiment ?

Answer : This was a research-managed on-farm **trial**.

Question 2 : What was the initial **soil P** level because the control **yielded** more than 1 t/ha ?

Answer : The initial P test **is** not **shown** here but **still** the **significant** increase in yield due to soil **amendment may** indicate that the initial P **supply may** be below optimum

Question 3 : How did **you** get to this regression equation ?

Answer : These were derived **from contrasts** and regression **from** 20 points and not **from 5 point-mean** data.

Question 4 : Why was combined **analysis** on performed on two site ?

Answer : **Only** these two sites were compatible for combined analysis following test on homogeneity of **variance**.

Question 5 : Why was not the **Split-plot** design used instead of the RCB **factorial** ?

Answer : Split-plot measures interactions better than main **effects** and is best applicable when large **differences** exist among main **factors**. **This certainly cannot say** among the main **factors** here. **Also**, the added **advantage** of factorial RCH is that it measures both main **effect** attd interaction **effect** with **equal precision**.

Question 6 : **What** do **you mean** by **Xmax** ?

Answer : By **Xmax**, I **mean** the amount of **input** needed to obtain maximum response. **It** only indicate treatment **effect** not optimum or economic level.

Question 7 : In what form was the **cow** manure ?

Answer : The cow manure was in the **dung** form not with **bedding/litter** as farmyard manure. It was reduced into smaller fragments to **increase** surface **area** for faster decomposition.

Project Activity Planning 1999-2000

Virginia State University : Kevin Brannan
Runoff Modeling with the KINEROS **model**

- Use :
- 1) Compare practices
 - 2) **Assist** in design and locating practices in watershed
 - 3) **Assist** in **monitoring**

Discussion

Question 1 : Can the model be **adopted under** the structures we have in Cape Verde ?

Answer : **Yes**, the structure I saw in Cape Verde like **stone** wall dams across **channels** because they have geometry.

Question 2 : How can the Gambia benefit from the model in terms of information on topography such as slope for cost/benefit analysis of erosion control practices.

Answer : I was involved in lots of modeling with the U. S. Soil and Water Conservation services and. the information can be used by economists for use in cost/benefit analysis.

The Gambia : Mohamed Kebbeh Farm Level Economic Programming/Policy

Applications : 1) evaluate the performance of improved technology
2) effect of risk
3) Questions of adaptation (who, what and how much).

Discussion

Question 1 : From your analysis in Gambia, fertilizer price is an important constraint to fertilizer use. This is important in the issue of soil nutrient mining. What we do to improve policy on fertilizer ?

Answer : We should try to make policy makers involve in the analysis and use of results. But how do we get the results to policy makers ? May be they should be exposed to fora like this.

Comments : It is a key issue and at this level, has been discussed at various cycles and at various levels even up to presidential. But, still the issue of making fertilizer affordable. It may also be useful to consider farmgate prices. For example, Gambia increased producer price for groundnut last year by 21% and fertilizer use is picking up. Farmer organizations can be very effective in pressuring governments to improve policy on inputs.

Recommendations

1. To harmonize methodologies on thematic InterCRSP field studies ;
2. To shorten research cycle as most of the topics being looked at now have been previously worked on and also if negative impact is not envisaged of technology being developed ;
3. Researchers argued in favor of long-term studies in order to be sure of what effect the developed technology would have on the environment ;
4. Mamadou Doumbia should use the results of nutrient balance studies to advice farmers of the implications of their practices on their soil quality ;
5. Need to explore agroforestry to fortify stoneline for runoff control ;
6. Need to explore biologically oriented cropping systems such as improved fallow and intercropping with high N fixing legume species for both soil fertility maintenance and soil and water conservation.

Minutes of the plenary session of InterCRSP

Thursday, January 14th, 1999

Chairman: Dr. Samuel Bruce-Oliver

Secretary: Dr. Abou Berthé

Dr. Yost in his introduction asked if countries have specific problems to discuss before he can move on project activities for the 3 years. He noticed that he has been involved in meeting with each country representatives except Mali to discuss budget. He will discuss this matter with Mali representatives in Bamako.

Representatives of country asked more informations about the following topics.

1. Baptista (Cap Vert) : When we can send receipts about expenses ?

Dr. Yost : You can send receipts as expenses are going on. Bank transfer can take at least 2 weeks.

Dr. Bruce : I think it will be better to indicate deadline to use funds by the time Dr. Yost gets to Hawaii. The budget has been cut to 60% in Year 2. It is possible to use the funds of the project to cover administrative and management costs (e-mail, fax, etc.,)

Dr. Yost : of course you can. For example, nutrient balance can be funded on on-farm trials. I advice you to combine activities across tasks in a very efficient ways to fit your situation.

Dr. Traoré Gaoussou : Do you have any mechanism to talk to the East group. You might have a combine workshop in Bamako.

Dr. Yost : I talked to the East group, but in an informal way. We need to work with INSAH for identifying the group. We might need some translation. The workshop cannot be in english next time.

Dr. Badiane : The main financial problem of the project is overhead costs. We are using all facilities at ISRA to make the project running.

Dr. Kebbeh : I suggest that 10% of Funds can be used for overhead expenses.

Dr. Yost: If there is some consensus, we might consider that situation.

Dr. Sene: Is it AID rules not have overhead.

Dr. Yost: I think it is allowed. Perhaps, I will be very happy to look for that. You are suggesting 10%.

Dr. Badiane: The other problem is **the** bill. We need funds to run. The labor **cannot** wait. They should **not cut** the **funds**. This year for **example** we **will** be doing our PRRA.

Dr. Yost: Receipts in our **financial** department are not too restrictive. I have nothing to do with this. **You** should be consistent with your accounting system.

Dr. Bruce: At least **you** give initial money to start with **the** activities. **After** that initial **fund**, the **system** of prefinancing will go on.

Dr. Sene: We are in year 2 now?, When year 1 did start.

Dr. Yost: First year was **from** may 1st 1997 to **April** 30th 1998. We had our trip in October 1997. All activities for year 2 should end by September 1999. I **don't** have a **straight** answer. **You** should spend all year 1 and year 2 funds by **March** 30 to avoid cutting. We got **cut** before, we didn't spend **all** the money.

Review of project tasks, present **status**, factors causing present status and revised completion date

Objective	T a s k s	Expected Output
1. Evaluate farmer PRRA practices		Report, Workshop presentation

Annual workshop in Year 2000, **January** 10 -- 14

Training task 33: cross visits consultancy reports, improved skills and programs

50% costs to be covered by receiving country
50% **cost** by **InterCRSP** Headquarters

Modou **Sene** : I would like to see cross visits as all groups getting together to visit **project** activities in a **country**

Dr. Gaoussou Traoré : I like cross visits. **Even you** have local expertise **you** need to ring in **somebody**. **You can** try also E-mail **conferences** among the **group**.

Annual work.shop pappers : Due date December 20th

Workshop proceedings : **March** 1, 1999

Annual reports **July** 15, 1999

Dr. Gaoussou Traoré :If **you** want your results to be largely disseminated, they should be in **french**.

Dr. **Sene** : Papers for Gambia should be in English
Mali and Senegal : **French**

Cap vert : Portugese

Dr. Brannan : Extension **fact sheets should be in national languages, but scientific papers might be in english**

Abstracts : English and french for paper executive summaries
Cut-off date for reports **Feb 1, 1999**

Forword for **proceedings will** be made by Dr. Yost.

Comments on Workplan needed: February 1, 1999
Workshop proceedings: April, 1999 (due date)
Annual reports (**progress report**) **July 15, 1999** . **Will have to submit** for September 1".
Annual workshop papers, due date for workshop papers , Jan 31, year 2000 in Bamako?

Country Workplan presentations

Senegal

Kineros model, PRRA
Cross visit t o u r

Yost: Farm level economic programming

Badiane: Kebbeh **will** give us **the formula** and data **requirements**. **Our** economist **can** nm the **model**.

Bruce: Are **you doing farmer** to fi-amer visit

Badiane: **Yes**, we do.

Mali

- Farming system research and natural resource management

1. **Task 2.6** Estimates of **runoff and soil loss** in Mali OHVN zone (use of **Kinero's** model)
2. **task 2.14** Farm level economic programming
3. **Task 3.23 On farm trial**
(**manure extender**)
- **contour line cultivation**
vegetating stone lines

4. **Task** 4.26 Farmer to farmer visit (contour line farming, organic matter production, agroforestry)
5. **task** 4.29 Field days **diffusion** (1 **und** table discussion with **NGO's** ,**Extension** and **commodity** research, etc. .)

- **Nutrient** Balance

1. Soil fertili restoration

PR&PDSS (SM activities)

2. Environmental impact assessment
3. GIS data development, **componen** of other activities

Gambia

- **Nutrient** balance study (Njaba **Ku da**)
- Farm level economic **programming** (incorporate other **crops** into the model)
- **Acidification** study
- **Runoff/soil** erosion study: **benefit** cost analysis for **different** erosion control strategies
- **On-fram** trails
- Pre-extension **fram** trials of the nutrient management study at Njaba Kunda
- **Assess** the **stability** of the **technology across different** farm conditions.
- **Framer** to farmer visits.
- **Impact** analysis
- **Environmental** impact study

Dr. Gaoussou Traoré (**INSAH**)

I don't see the relationship of your **workplan** and farmers' needs.

Diack: What are the norms for **water** quality?

Kevin: Maximum contaminated level : 10 ppm for **Nitrogen**

They are **well** established for **pesticide**

Dr. Yost: some pesticides are known to be leachers. Pesticides are **difficult** and costly to **analyze**. **You can** make a **list** of pesticides used in CMDT zones and we will rank them as **leaching** or as no leaching.

Minimum concentration level (mcl) is set for a lot of pesticides.

Cap Vert

- **Nutrient** balance study (com, pea at, beans and banana) at two locations
I need some **references** on that work.

Available **references** are from: **Gigou**, 1980's and **Pieri** 1978 in Senegal
(Agronomie tropicale)
 smaling
 Van der pool and **Nick** in Mali

- Runoff studies (**Kinero's** model)
- Farm **level** economic **programming &** adoption studies
- Environmental **impact study (salt intrusion and pesticides)**
- **On-farm trials** (two locations)
- **Integrate crop** and forage **systems**, (biomass yield and build-up of SOM)
- Farmer to farmer **visit**
- Regional impact (GIS **cover of the** watershed)

Badiane: **meet** deadline

Dr. **Gaoussou** Traoré (INSAH):

- **send** a report to INSAH
- **Bring** others **groups** for next **year** workshop
- Internal discussion of reports in **each country** before **coming** to the group.

Dr. Bruce: Take an opportunity to **thank** all participants, Badiane, people to **Kaolack**.
Thank you very much again

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Programme of the Intercrsp West group workshop
Kaolack, Senegal January 11-14, 1999

Sunday januray 10th, Arrival of the participants and departure for Kaolack

Monday, january 11,

9h30 - 10h15 : Opening ceremony

. Dr. Russe1 YOST

≡≡ Dr. Gaoussou TRAORE

≡≡ DG / ISRA

10h15 - 10h30 : Coffee break

10h30 - 11 h30 : Keynotes adresses

Chairman : Dr. J.P. NDIAYE

Secretary : Ms. SIDIBE

10h30 - 1 lh : Dr. Gaoussou TRAORE

1 lh -- 1 lh30 : Dr. Russell YOST

Theme 1 : Farm Programming and Country policy

1 1h30 - 1 lh50 : Cape Verde

1 lh50 - 12h10 : The Gambia

12h10 - 12h30 : Mali

12h 30 - 12h50 : Senegal

12h50 - 13h30 : General Discussions

13h30 - 14h30 : Lunch Break

Theme 2 : Soil / Water Conservation

14h30 - 14h50 : Mali

14h50 - 15h10 : Senegal

15h 10 - 16h30 : Discussions

Tuesday, january 12th

Chairtnan : Dr. Gaoussou TRAORE

Secretary : Mr. Babou JOBE

Theme 3 : Nutrient management

9h - 9h20 : Cape Verde

9h20 - 9h40 : The Gambia

9h40 - 10h20 : Mali (2 présentations)

10h20 - 1 1h00 : Senegal (2 presentations)

11 h00 – 1 1h20 : Break
 1 1h20 – 13 h 00 : Discussion
 13h00 – 14h00 : Lunch break

Theme 4 :Environmental Impact

14h00 – 14h20 : Mali
 14h20 – 14h40 : Discussion

Theme 5 : Project Activities Planning

14h40 – 15h15 : **Runoff/Erosion Control** (M. SENE and K. BRANNAN)
 15h15 – 15h45 : **Nutrient management** (M. DOUMBIA)
 15h45 – 16h15 : **Farm level economic programming/policy** (M. KEBBEH)
 16h15 – 17h30 : Discussion (GIS)

Wednesday, janusry 13th

7h30 – 13h30

Fidd trip : Niore and Koutango Sites

Thursday, january 14th

Plenary session

Chairman : Dr. Samuel BRUCE-OLIVER
Secretary : Dr. Abou Berthe

9h00 – 10h30 : **Project management (IRYOST)**
 1 0h30 – 10h45 : Break
 10h45 – 12h45 : **Countries presentations (Plans and Taks)**
 12h45 – 13h30 : Wrap up meeting
 13h30 – 14h30 : Break
 15h00 : **DEPARTURE from KAOLAC K**