AN INVESTIGATION OF THE SOIL, FORESTRY, AND AGRICULTURAL RESOURCES OF THE PITA REGION OF THE REPUBLIC OF GUINEA

Findings from a Field Investigation
and
Recommendation for their Improvement

By

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Notes on

"AN INVESTIGATION OF THE SOIL, FORESTRY, AND AGRICULTURAL RESOURCES OF THE PITA REGION OF THE REPUBLIC OF GUINEA"

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This report was completed in January, 1985, under contract 675-0410-5-00-8402-00 with the AID Affairs Office Conakry and reviewed in February, 1988. Its purpose was to investigate soil and forestry resources of the Pita Region of the Fouta-Djallon Region with respect to their improvement. Special emphasis was given to the enduring impacts that trees and shrubs were having on soil characteristics and productivity.

Since the submission of the report, it has been reviewed and additional data are available which should be included. Moreover, the African Bureau of USAID has initiated the Natural Resource Management Support Project. The following observations should make this report more useful for that project.

Abstract, #1. In addition to the contributions of soil organic matter noted here, Hue et al. (1986) reported on data showing that soil organic matter reduces Al phytotoxicity. Foy (1971) noted that humic acids lowers the pH at which plants are injured in certain acid soils. Data indicate that Al toxicity occurs at a higher pH in soils whose predominate clay mineral is kaolinite than in soils whose major clay components are vermiculite and montmorillonite. Ahmad and Tan (1986) reported that soil organic matter was as effective as lime in reducing Al toxicity. Given the seriousness of soil acidity in the Fouta-Djallon and the predominance of 1:1 and amorphous clay components, the buffering role of soil organic matter is extremely important for sustaining long-term productivity. And, given that sustained use of lime is not likely to be financially viable at the farm level in most of the Fouta-Djallon, the roles of soil organic matter in reducing Al phytoxicity and buffering acidification becomes even more important.

Abstract, #2. A major objective of the study was to identify the more productive farming systems in the Pita area to use as models for development and extension of improved technology. It was reasoned that techniques and systems developed in the Fouta-Djallon will have a high probability of being extended in the area relative to technologies which are brought in from the outside. The "tapade" system was the most widely seen technology having an impact on productivity. This system, discussed in the report, offers opportunity for improvement and extension. Initiatives aimed at increasing productivity in the Fouta-Djallon should examine this system as a model before elaborating

development and extension of new systems.

P. 5, #3. This sentence should read "Woody perennials play a vital role in soil-building in the Fouta-Djallon." Given the long dry season, most grasses have a limited time of the year to be part of the soil-building process, and treees were found to be mining deeper soil horizons than grasses. In addition, the grass cover is often gone by the beginning of the rainy season when erosion potential is high. Thus, we are not saying that trees and shrubs are superior to grasses so much as noting that grass cover is limited during critical times of the year, and that grass cover is often greater under perennials than in the open. These observations are extremely important to keep in mind when formulating plans to restore the productivity of the Fouta-Djallon. See Charreau (1974) among others for comparative data on soil-building and conservation under various land covers.

P. 6, #4. This sentence should read that soil pH below 5.5 affects the growth and vigor of many economically important plants. Obviously, many plants continue to grow at pH below 5.5. But, as noted, toxicities and nutrient defiencies increase below about 5.5. Biological N fixation is particularly affected below 5.5 because of the reduced availability of Mo, a vital element in the process. Leucaena trees in plantations on acidic soils were lacking in vigor, and we noted that hair-root development was particularly poor--a sympton of Al-toxicity.

P. 6, #5. Dr. P. A. Sanchez noted that soil organic matter "complexes" free forms of aluminum and iron. The term "fixes" is more properly used in biological process of converting atmospheric N to a form useable by plants. With respect to soil organic matter's capacity to complex free aluminum, Hue et al. (1986) have published data since this report on this phenomena.

P. 6, #6. The apparent correlation between truncated fallows and acidification has raised questions. First, a broader sample in the Pita area is required to assess whether shorter fallow periods are related to acidification. Second, the working hypothesis here is that once the perennial vegetation is replaced by cultivation of annual grains such as "fonio", the annual production of organic matter decreases. Since, it appears from data collected during the study and from the literature that acidification through aluminum hydrolysis is buffered by soil organic matter, it would follow that reduced periods of perennial-dominated fallows would lead to increased rates of hydolysis.

P. 10, #7. Unfortunately, the analyses of the samples delivered to the lab were not conducted. The correlations between soil organic matter and parameters noted on page 10 would give us valuable clues as to where the organic matter is having the impact.

P. 16. #8. This hypothesis is built upon the perennial nature of woody plants which allows deep-cycling and year-around

cover. Besides the contributions of trees and shrubs noted in the text, there is an additional observation that is often ignored: unlike many ecological systems of more temperate zones, in the Fouta-Djallon, there is more grass found under many trees and shrubs than found in the open. Thus, it is more technically correct to say that a system of trees and grasses together are generally more effective than grasses in soil-building and erosion control.

P. 22. #9. Last sentence should read that organic matter complexes Al and Fe rendering them <u>less</u> soluble.

P. 23, #10. Doerge et al. (1985) found a similiar response to Mo fertilizer from alfalfa on an acid soil.

P. 24, #11. It would be a simple matter to collect samples and test for OM%, pH, and Al%, and it is suggested that assessment teams do this. Examination of the correlations among these parameters would provide data to test the hypothesis that higher levels of soil organic matter in the tapade systems significantly buffers soil acidity and reduces free aluminum. These data may provide clues about financially-viable ways to manage the soils in the Fouta-Djalon. Vertical split-root techniques may provide additional information about the effects of various soil characteristics on growth and development of various plants. Using plastic nursery pots (about 30 cm in height), fill the pot about 2/3s up with soil from unproductive fonio fields (this will be the sub-soil). These pots will be the control. To test various treatments, amend the fonio soil with Mo fertilizer, ashes, lime, and various amounts and types of organic matter and fill up other pots with about 20 cm of soil. Add about 8 cm of "tapade" soil to all treatment and control pots. Grow sensitive plants such as Leucaena in the pots and examine the response of the roots to various treatments of the soil in the botton of the pot. Within two weeks, one should be able to visually compare the root growth in the sub-soil of the various treatments. (To reduce the possibility of migration of nutrients from the "top" soil to the subsoil, watering could be done by allowing the soil to draw water up from water in trays by capillary rise.)

P. 26, #12. Laterization as a process is still a topic of study and debate. As noted in the report, the depth of the soil over indurated pans were generally greater under a tree and bush cover than under grass. Following is a paragraph from E. W. Russell (1973) that was of interest in checking our observations against the literature (p. 731): "Laterites vary considerably in the additional irreversible hardening they undergo on drying, and there may be laterite layers near to the surface that undergo only a moderate degree of irreversible hardening on drying. Such layers are found under forest in parts of West Africa, and are soft and permeable under forest, but if the forest is cleared and the land goes under cultivation, they will form a hard survace crust, probably after the topsoil has been

lost by erosion, making the land quite unusable for agriculture. Fortunately these ironstone or laterite crusts soften again if the land is replanted to forests, though it may take several decades for the whole crust to be softened." It probably does not make financial sense to attempt to reclaim laterized soil with trees plantings, but Russell's writings and our observations suggest that it makes good sense in all ways to manage the soils of the Fouta in such a way as to maintain some vegetative cover. Fortunately, systems have been developed in the Fouta which permit both annual harvests of food, forage, and wood and maintain the cover. These systems merit close examination by any agency supporting smallholder development.

P. 31, #13. It is strongly suggested that any projects in the Fouta-Djallon take a very close look at the Tapade system as a possible model for development of technologies. We understood that these systems have been in place for generations, and, while it is a very effective system, they are limited as they are presently used. They could be improved upon with the improved systems having a high probability of being successfully transfered.

P. 41, #14. The Guesselbodi Model Site in the USAID-supported Forest Land-Use Project in Niger represents an excellent example of the effectiveness of natural resource management for sustained-yields of wood and forage. And, it represents an excellent model of how the central government and local cooperatives can share the stewardship of natural resources and the sustained benefits that accrue from that management. It is suggested that project managers in Guinea accompany GOS officials to Niger to visit the Guesselbodi Model Site and discuss both the policy conditions and management system with Government of Niger officials.

P. 49, #15. This should read "Woody perennials are an integral part of the soil-building process." Their roles are extensively discussed above.

This report contains the findings and recommendations from an eight-week investigation of the soil and forest reserves of the Pita Prefecture in the Republic of Guinea. The investigation was undertaken under USAID contract 675-0410-5-00-8402-00 between AID Affairs Office/Conakry and Michael L. McGahuey.

The purpose of the investigation was to study the soil and forest resources of the Pita region with respect to their improvement. This report is divided into the following sections:

1. Introduction: general overview of the purpose, findings, and conclusions of the investigation;
2. Materials and Methods: description of the activities and approaches of the investigation;
3. Results and Discussion: presentation and analysis of the findings;
4. Conclusions and Recommendations: summary and strategy;
5. Appendices.

ABSTRACT

Small-holders in the Pita region are providing food and fuel for their families with increasing difficulty. Yields of grain and fuelwood are progressively declining, and pastures which must sustain growing animal herds are decreasing in size and quality. Overuse of the soil's resources, which has produced this development, continues as the population grows. At this critical time of increasing growth and pressure, we see a situation where the soil has not only become less productive but less capable of regeneration. Without the development of an effective and appropriate strategy that would restore the soil's productivity, the future quality of life for the Pita region small-holder cannot be assured. But, the farmland is limited and any strategy to improve productivity must permit the annual harvests of food, fuel, and forage to continue.

The primary causes of the reduction in soil productivity are soil acidity and low nutrient content. Overcultivation and overgrazing have produced a condition where plant nutrients are easily leached from the topsoil, and where the concentration of acid-generating aluminum has increased. The present conditions can be largely attributed to the loss of the tree and shrub cover which has been steadily lost to the hoe, to fire, to fuelwood gathering, and to increased grazing. This deep-rooted vegetative blanket not only protected the soil from eroding during the intensive rainstorms of the Pita region, but it also recycled leached nutrients from the lower soil horizons, and it enriched the soil with organic matter. Organic matter is not only high in nutrients, but it is extremely effective in holding plant nutrients against leaching. #1 (#1)

Options to current strategies were considered. The findings of this investigation determined that the simultaneous cultivation of food, fuel and pasture crops on the farmland (multi-cropping) would be the most effective and appropriate way to build and maintain a perpetual soil cover while increasing annual harvests of food, fuel and forage. Modernization of agriculture based upon inputs of capital-intensive fertilizers and lime may one day aid the small-holder to increase productivity, but many conditions beyond his control must change before he could assume the risk and the recurrent costs.

Multicropping is effectively practiced in the Pita region as well as the rest of West Africa. Herbaceous annuals and woody perennials are integrated within the system such that a large part of the soil profile is explored and plant canopies provide soil cover throughout the year. Food and forage are provided during each season by different plants.

This investigation studied the components of several traditional systems as well as basic agronomic and soil principles to form an appropriate strategy. This strategy was built by integrating the disciplines and plant species of agriculture, forestry, and range management with selective traditional practices. It may be termed integrated crop management. In its essence there are no recurrent obligations. Its extension should be facilitated by the predominance of practices familiar to the Pita small-holder. (#2)

It is vital that small-holders have first-hand knowledge of a new strategy in order to judge the merits of a scheme. Findings from this investigation suggest that The Pita Community Forestry would serve as an excellent model for an integrated crop management strategy. The emphasis of the Project should be expanded to include the establishment of grasses, browse shrubs, and living hedges. The activities should be continued through the harvests of each crop. After the initial harvests they will be able to compare the harvest of food, pasture, construction material, and fuel against the yields of the current practices. Small-holders should continue to contribute their ideas and experience to the development of the new strategy.

Table of Contents

	page
Introduction	2
Materials and Methods	10
Findings and Discussion	15
A. Summary of the Findings	
B. Soils of the Pita Prefecture: Their Nature and the Genesis of Degradation	17
1. Classification and Characteristics	
2. Acidification	21
3. Amending Acidic Soils	24
4. Laterization	25
5. Summary of Characteristics of Pita Soils	
C. Food Production Systems in the Pita Region	28
D. Fuelwood Reserves of the Pita Region	32
E. Pastoral Systems on the Fouta-Djalon Platuea	38
F. Fallows in the Pita Region: Multi-Purpose Reserves	41
1. Effects of Fallow Vegetation on Tropical Soils	
2. Genesis and Consequences of Degraded Fallows	47
G. Field and Brush Fires	48
H. Economic Constraints to Agricultural Development in the Pita Region	50
I. Monsieur Bary's Farm: A Case Study of a Successful Small-Holding Farmer	53
Conclusions and Recommendations	61
A. Summary of Conclusions	
B. Expansion and Continuation of the Pita Community Forestry Project	
C. Integrated Crop Management Model	62
1. Implementation Plan	
2. The Crops	65
3. Potting Soil Preparations	66
4. Ashes	71
5. Erosion Control	72
Appendices	73

INTRODUCTION

The Pita region is on the Fouta-Djalon Plateau of Central Guinea where demographic pressure, capricious climate, poor husbandry, and fragile soils with potential for acidification and erosion have placed the livelihood of the small-holder in jeopardy. Fuelwood reserves are severely reduced, agricultural production is decreasing, and the quality and quantity of pasturelands are being increasingly impoverished. Fuel wood procurement consumes progressively larger portions of time and income (LaFramboise, 1984); grain yields are reportedly one half of those harvested one generation ago; and pastures are being progressively overgrazed.

The findings from this investigation indicate that the Pita region small-holder can be helped by a strategy of intercropping food, forestry and pasture species. Unfortunately, agronomists, foresters and range scientists often take adversarial postures with respect to one another. These conflicts should not be allowed to occur in the Pita region. The integration of these disciplines would increase production of food, fuel, and pasture for the small-holder.

The climate of the Pita region increases potential for soil erosion, leaching and acidification. The five month growing season is characterized by intensive rainfall events. The protective vegetative cover is badly degraded and much of the total rainfall (1200 - 1600 mm/yr) runs off carrying soil particles. Or, with little soil organic matter to retain it, the water rapidly passes through the soil and flushes plant nutrients from the topsoil to the

lower horizons, below the reaches of crop roots. This leaching also robs the soil of its capacity to buffer acidification. Consequently, soil productivity is decreasing and soil regeneration is becoming increasing difficult. The impact of these developments falls most heavily on the small-holding farmer who, lacking a reliable market for commodity crop production, depends upon his farmland to provide his family's sustenance.

Small-holders, who make up 70 to 80% of the population in the Pita region (Stephanesko, 1982), are subsistent farmers whose first concerns are the family's food and cooking fuel supply. Clearly, serious shortages of both will face them if the current trend continues. The situation demands the immediate implementation of a time-proven strategy that will ensure the long-term productivity of the Pita region farmlands. But, that strategy can not ignore the short-term subsistent necessities of the small-holding family or the economic constraints of Guinea.

The formation of an appropriate strategy would require consideration of the following:

1. The strategy must be widely adaptable and without recurrent costs to the small-holder;
2. Its formation should not anticipate rapid fundamental changes in the GOG development services or in the in-country transportation system;
3. It must place the small-holder in a position where he can ensure his family's livelihood independent of the international marketplace;
4. It should allow the enterprising farmer the means to climb above the subsistent level; and,
5. The successful extension of any new strategy requires a pilot demonstration providing hard proof to the small-holder that it is more effective and that it does not increase risk of sub-marginal harvests.

In essence, the immediate need requires a strategy based upon technology that has been tried and proven under circumstances similiar to those of the Pita region small-holder and which accomodates annual harvests and a perpetual soil cover. And, in designing a strategy, it must be recognized that the Pita region and the tropics in general have opportunities and limits with respect to food production that are different than the temperate zones.

Agriculture, forestry and range management are natural allies in the tropical environment, and the integration of those disciplines is required to form the most effective and appropriate strategy. To begin, the small-holder depends upon trees and shrubs to recycle nutrients to the topsoil of his grain fields. He does not have the economic resources to purchase fertilizers, and, as will be discussed later, it is not likely that the small-holders economic status will change rapidly. Thus, loss of perennials will continue to result in an impoverished soil. Secondly, the herder depends upon trees, shrubs and grain crop litter as browse. And, the grazing of animals in grain fields during the dry season concentrates manure deposits. Thirdly, leaving perennials on crop and pasture land provides a reservoir of fuelwood. While multicropping food, fuel, and pasture species on the same land is not common in the temperate zones, it is widely and successfully practiced in the tropical areas.

Many of these time-proven integration of trees, shrubs and annuals are found in Guinea and other parts of West Africa where they provide sustained yields of food, fuel, and pasture. For one reason or another, these indigenous, readily-transferable technologies have been largely discounted by the scientific community until recently. This is one reason why they have been

little extended across West Africa. However, results from at least seven British and French research projects are now available which quantifies the benefits of some of these practices (Felker, 1978)

The design of the strategy requires that the nature of the basic problems facing the Pita region small-holder be identified. Toward that end, this investigation found the losses of soil productivity and fuelwood reserves to the progressive erosion of the soil's vegetative cover. Increased farming pressure, overgrazing, extensive brush fires, and increased harvests of young shrubs and trees for fencing have destroyed surface mulches and degraded the vegetative blanket which rebuilds the topsoil.

Under traditional husbandry, farmers periodically took marginally productive land out of cultivation to fallow or rest it. The vegetative blanket that grew during the fallow period regenerated the soil's productivity through additions of organic matter and plant nutrients to the topsoil. To ensure harvests of 500 to 700 kg of grain per hectare, the typical small-holder in the Pita region used a ratio of ten to fourteen years of fallow to four or five years of cultivation. Until recent times the solution to population increase was to clear virgin land for additional farmland. However, there is little virgin arable land remaining in the Pita region, and demographic pressure continues to grow, just as grain yields continue to decline. To compensate for the lesser yields, small-holders put more land under cultivation which further reduces the fallow period. Thus, we currently see fallow periods of three to five years and yields of 200 -300 kg/ha.

The ramifications of shortened fallows go beyond reducing time for fallow vegetation to rebuild the soil. The constitution of the vegetative blanket is as important as the length of fallow in improving the soil's productivity. Ft3 Soil building in the tropics is more effectively done by woody perennials

which establish dominance during long fallow periods. But the vegetative blanket in the Pita region is progressively predominated by annual grasses. Shallow-rooted grasses deplete the topsoil without cycling leached nutrients from the deeper soil horizons or strata. The easily leached elements include calcium and magnesium. These two nutrients buffer against acidification as well as being necessary for plant growth and development. As they are lost from the topsoil, the concentration of aluminum and iron increases. It is the predominance of aluminum and iron that has been identified as the primary cause of further acidification in acid soils (Tisdale, 1975).

Soil acidity generally reduces crop vigor. Few plants continue to thrive #4 under increasing acidic conditions once soil pH has dropped to about 5.5. Negative effects upon plants generally do not come directly from the acidity itself, but from associated deficiencies and/or toxicities. Calcium, magnesium, phosphorous, and molybdenum are the main plant nutrients found in deficient concentrations in acidic soils. Aluminum and manganese are increasingly soluble as soil pH drops from 5.5 to 4.5 and can occur in toxic concentrations in that range.

Soil organic matter from decomposing plant material can mitigate the acidifying reaction by fixing the free forms of iron and aluminum (Sanchez, #5 1976), and it can enrich the topsoil in recycled plant nutrients. But the truncated and impoverished fallows in the Pita region supply decreasing amounts of plant litter. Consequently the buffering effect of soil organic matter is reduced and soil acidification is accelerated. Fewer plants thrive in the more #6 acidic environment and plant litter and nutrient cycling are further reduced.

The small-holder in the region finds himself in a vicious spiral. He farms soil which progressively yields less grain as the fallow periods are increasingly shortened. Since virtually all the land in the Pita region is currently in the fallow or cultivation rotations, he must reduce the fallow periods to compensate for the reduced yields. In short, the Pita small-holder is a victim of an ecological disequilibrium in which soil regeneration has become increasingly difficult, and the traditional means to restore soil productivity have been largely eliminated. The circumstances are progressively robbing him of his ability to provide for his family.

The findings of this investigation strongly suggest that small-holders in the Pita region be provided with a model that at a minimum, demonstrates a strategy that would increase productivity of food crops, rebuild the soil, and reduce risks of periodic food shortfalls. Secondarily, the model would provide the progressive small-holder with technology to increase commodity crop production as the marketing opportunities arise. The basic strategy can not include elements which increase risk.

While no development program is currently underway that specifically targets the food production of the Pita region small-holder, the USAID/GOG Community Forestry Project should be expanded and extended to serve as an appropriate model. The fuelwood situation, which in many respects is as serious for the small-holder as shortfalls in food harvests, is being faced at the village level by this self-help project directed from Pita by the GOG Forestry Service and a U.S. Forester. Although, fuelwood production is the primary objective of the Community Forestry Project important secondary objectives include soil enrichment, and production of browse from the trees.

The existing project should be expanded in scope to emphasize multi-cropping. Other crops would be interplanted with the fuelwood species for concurrent production of food, fuel, and pasture And, just as importantly, integrating diverse crops provides a more effective vegetative blanket to build and maintain soil productivity. The blanket would be composed of cereals, fodder grasses, pulses (herbaceous legumes), shrubs and trees. An integrated crop management strategy would provide a multi-story root profile, perennial ground cover, and a reliable and varied source of food, pasture and fuel. (The strategy in fact contains many elements used by Pita region farmers for generations to maintain continual food production in "tapade" garden beds.)

The Community Forestry Project has the manifold advantage of farmer participation. The new model should continue to take advantage of that input. For one, the progressive small-holder will have the opportunity to contribute his ideas and experience. Secondly, participants will have first-hand experience in implementing new practices without putting their families' livelihood in jeopardy.

The results from the investigation suggested that most small-holders are not in a position to increase productivity through modernization. Numerous problems beyond the control of the small-holder will have to be resolved before capital-intensive technology will have an impact. To begin, the large majority do not have the surplus necessary to accept additional risk. Secondly, the lack of an adequately mobile extension service and a reliable transportation system places in jeopardy the timely delivery of materials (fertilizers, lime, pesticides, etc.) or technical information to the small-holders. Finally, the vagaries of the international marketplace and the fertilizer industry place the small-holder in a precarious position. During times of a decreasing market for

his produce or a petroleum crisis that would affect fertilizer prices and supplies, the small-holder would be the first affected and least capable of surviving the crisis.

Modernization would have to be supported by an intensive agribusiness network. The history of agribusiness in Guinea has illustrated the above pitfalls. A number of produce processing enterprises were started in the last several years, but they have not proven to be sufficiently competitive to provide a reliable market for the Guinean small-holder. In fact, the periodic glut of some fruits and vegetables in the Pita region pinpoint distribution as a major impediment to commodity crop production. Increasing productivity through modernization has a theoretical attractiveness and offers potential, but hard realities and inherent risks preclude it as a strategy of first approach to relieve the chronic threat of food shortage.

MATERIALS AND METHODS

The objectives of this study focussed on the nature of the acidic soils of the Pita region with respect to their amendment for increased production of food, fuel and pasture. Secondarily, numerous interviews were done and the literature was reviewed to ascertain the potential and constraints of strategies to improve productivity. Particular attention was paid to identifying technology that could be most easily transferred to the Pita region small-holder.

Evidence from other studies suggested that soil conditions could be improved by enriching the soil's vegetative blanket and increasing the soil organic matter. The hypothesis that the vegetative cover can significantly affect soil productivity was studied by comparing soil properties under various types of vegetative cover. Data were collected from two different field studies: 1) during the present investigation, soil pits were dug on twelve sites with contrasting soil cover; and 2) in 1976, scientists analyzed soil sampled from the Baring Research Station. In both studies soil vegetation gradients provided the opportunity to test the hypothesis. The parameters chosen for analysis were the soil properties most influenced by the vegetative cover. They are pH, CEC, percent organic matter and %BS. In addition, available P was correlated with organic matter.

During the present investigation, soil samples were collected from the various horizons in the pit profiles and sent to the National Soils Laboratory #7 at Falaya. The results from the analysis had yet to be recieved at the time this report was written; hopefully, they can be analyzed shortly.

Data from the Baring Research Station permitted correlations between organic matter and pH and between organic matter and available P. The CEC and %BS data were not available.

Interviews were done with a wide range of individuals in order to build as complete a picture as possible of the problems and opportunities facing the Pita region small-holder. Following is a partial list of those individuals:

Washington D. C.

-Drs Gill, Meyer, and Fredericks and Mr. Michael Benge in the Office of Agriculture, Bureau for Science and Technology, AID. This office provides technical expertise in soils, agriculture, microbiology. This visit was especially helpful in procuring acid tolerant Rhizobium and in setting up the field investigation. Mr. Benge is an expert on Leucaena and may be able to provide germ plasm.

- Professor W.S. Buol of the Soil Science Department of North Carolina State University. Contacted by phone, Dr. Buol was extremely helpful in identifying the most useful soil parameters for the field investigation. He has extensive experience with tropical soils.

-Mr. Jeff Gritzner, NAS. Mr. Gritzner provided resource material on Guinea and identified tropical Rhizobium work being carried out in West Africa. His office is very active in monitoring a wide range of agrosilvipastoral projects in the tropics

-Mr. Tom Catterson, Senior Forestry Advisor, Bureau of Africa, AID. Mr. Catterson is the coordinator for West African Forestry Projects. His office is a valuable resource for information concerning AID and other projects as well as a technical backstop.

-Dr. Frances Gulick, consultant, Office of Technical Resources, Bureau for Africa, AID. Dr. Gulick recently submitted a proposal title "Increasing Agricultural Food Production through Selected Tree Planting Techniques," which catalogues the studies done on links between tree cover and food crop production. She is working to quantify this relationship as much as possible to build interest in its use to increase food production.

Conakry

-Mr. Mark Wentling and Mr. George Branson, AID Director and Administrative Assistant, respectfully. Both have been involved with the Community Forestry Project for the last two years.

-Dr. Y. Camara, Director of SENASOL. He provided us with a soils map of the Pita region. He participated in the production of the map. His lab can do limited soil testing.

-Mr.Djalo, Director of Water and Forests. Mr. Djalo is long time Director of his department. He was very interested in trying new species in the Pita region.

Centre Zootechnique, Falaya

-Dr. Keri is the Director of the Soils Laboratory at this Agricultural University. We dropped 28 sample with him to test pH, CEC, %BS, organic matter content and available P. He was to find CEC with a non-buffered solution so as to measure that parameter at the soil pH.

Pita and Labe

-M. Sangare, Forestry Engineer with the GOG, Administrative Director of the Pita Community Forestry Project. Mr. Sangare provided me with technical information and made arrangements to meet with GOG personnel.

-David LaFramboise, Forestry Specialist Contractor with USAID, Technical Director for the Pita Community Forestry Project. Mr. LaFramboise was my principal contact during the investigation. He has been with the project since the beginning.

-General Sow, Director of Rural Development of the Pita region. General Sow is an agronomist as well as administrator. He provided valuable information on soils, husbandries, vegetative covers, land use history, demographics and indicator plants.

-Project Field Personell: Messieurs Camara, Balde, Syla, and Lando. They are trained foresters and agronomist with varying degree of experience in the field. As a composite, they provide a wealth of information.

-Mr. Stephanesko, Director of the FAO Cattle Production Project. He has wide experience in tropical pastures and is a valuable resource for possible exotics for use in the Pita region.

-Dr. Gupta, Director of the FAO Integrated Management Project of the Fouta-Djalon. He has extensive experience in tropical forestry. He is planning to stay in Labe for about two years.

-M. Bary, Small-holding Farmer. M. Bary is an extremely progressive who is interested in establishing his own tree nursery and fuelwood plantation. His farming techniques were worth studying as components for an integrated crop management model.

-M. Sekou Lere, Agrochemist at the Baring Research Center. He has been at the center for ten years and has collected soil's data over several years. We used his data to correlate pH with organic matter content.

-Dr. Mani, veterinarian for the Pita District. He has extensive experience with the nutritional aspect of animal husbandry. One of his major problems is the lack of transport to reach the District's herds. He has sufficient vaccine but no means to get to the animals.

-Mr. Foinke, Adjoint to the Director of Forestry in Pita. He provided a list of preferred fuelwood species, of tree species which are disappearing, of preferred browse species, and of field experiments.

-Sori Doura Traore, Director of Agriculture. He provided information on legume species and on agricultural methods.

FINDINGS AND DISCUSSION

The recommendations for improving the productivity of the smallholding farmer were based upon the findings of this investigation. And, it was recognized that others may make different conclusions from these findings. For these reasons the findings were presented and discussed in detail. Given the length of this section, a summary precedes the main body.

Summary of the Findings

1. The Pita region is dominated by Ferralitic soils which are acidic and impoverished from overuse and lack of vegetative cover.
   a. The topsoil has been leached of basic cations and is probably enriched with aluminum and iron.
   b. It is now recognized that the primary source of soil acidity is the hydrolytic reactions of aluminum and iron.
   c. Phosphorous deficiencies appear to be a major constraint in acidic soils.
   d. Calcium, magnesium, and molybdenum deficiencies must be suspected in acidic soils (pH < 5.5).
   e. Toxic levels of aluminum and manganese are highly probable in acidic soils.
2. Demographic pressure and extensive field burning has degraded the soil's vegetative cover and eroded soil organic matter content.
   a. Traditional husbandry employed relatively long periods of fallow dominated by woody, deep-rooted perennials to restore soil productivity; but the current fallows are often less than five years and predominated by grass.

b. Fuelwood demands degrade forests and woody fallows.

c. Increased animal herds increase dry season pressure on woody foliage and sprouts.

d. Annual brush fires destroy living and dead soil cover.

e. Brushy fallows are increasingly thinned of brush and young trees for use as fencing.

f. Economic and infrastructural constraints restrict use of manufactured fertilizers, lime and equipment to increases productivity.

3. Forest reserves of the Pita region are being used faster than they are regenerating.

a. Villagers are having to walk farther for fuelwood.

b. Townspeople must pay progressively more for fuelwood.

c. Prefered tree species are disappearing at a rate proportionate to their distance from population centers.

4. Increasing soil organic matter may buffer excessive acidity (pH < 5.6-5.8).

a. Humus may complex free aluminum and iron and reduce the rate of the hydrolysis.

b. Data from the investigation and from the literature support this hypothesis.

5. A farming system is required that maintains a perpetual soil cover on the same land that provides annual and reliable harvests of food, fuel, and pasture.

a. Trees and brush are a more effective cover in the tropics than annual grasses #8

b. The Pita Community Firewood Project has been succesful at extending the fuelwood crop concept to Pita region villagers.

b. The Project should be expanded in scope to include food and pasture species and extended until the initial harvests.

c. Superior practices of traditional husbandries have been identified which should be considered for inclusion in the expanded project.

Soils of the Pita Prefecture: Their Nature and Genesis of Degradation

Classification and Characteristics

SENASOL, Service Nationale des Sols, describes three general classes of soils found in the Pita region (1982). Ferralitic and Hydromorphic soils are noted as most apt for agriculture, whereas Skeletal soils are limited by depth. Ferralitic soils are most widespread and predominate the farmland. SENASOL identifies the principle constraints to crop production on those soils as acidity (pH 4.5-5.5) and low organic matter content.

Ferralitic soils are generally found in humid or semi-humid tropical regions where intensive rainfall and high temperatures play major roles in soil formation (pedogenesis). Consequently, the agronomic value of Ferralitic soils is largely determined by soil characteristics which are most influenced by weathering. Those include soil pH, cation exchange capacity (CEC) and percent base saturation (%BS). Coincidentally, these three characteristics are also affected by the soil vegetative cover.

In studying ways to improve the agricultural productivity of the soils in the Pita region, it is important to choose parameters which can be amended by the soil's vegetative cover. While Pita region small-holders are not currently in an economic position to support the use of fertilizer, lime or machinery, they can (and do) manage soil vegetation to improve soil pH, CEC and %BS, which in turn improve productivity.

Soil pH

Soil pH is the measure of soil acidity. The pH ranges from 0 to 14 with pure water (neutral) at 7.0. Acidic solutions are those less than 7.0; the lower the pH, the more acidic the solution. Soils of the humid tropics are generally regarded as acidic (pH 5.0-6.0), while humid temperate soils typically range from slightly acidic to neutral (pH 6.0- 7.0). The difference in soil pH between the two climatic regions is largely due to leaching. (The process of acidification will be discussed in the following section.)

Soil pH is often cited as the one most single important soil parameter in terms of crop management. First, the availability of plant nutrients in the soil solution is a function of soil pH. Thus, defeciencies and toxicities can be inferred from the pH. Secondly, much of the cation exchange capacity of the tropical soils is pH dependent; an increase in pH produces an increase in CEC. Thirdly, the constitution of the soil microbial population depends upon pH, and food production depends to a large degree upon that constitution.

Cation Exchange Capacity (CEC)

The cation exchange capacity is the measure of a soil's ability to hold positively-charged ions (cations) against leaching. The retention of cations is possible because particles of clay and organic matter in the soil have

negatively-charged (electronegative) sites on their surfaces. These sites attract and hold cations in the soil solution (Ca, Mg, K, Na, NH4, Al). The significance of CEC is clearer when one considers the importance of those cations with respect to plant growth and soil properties.

Cation exchange capacity is a function of the surface area of the soil particles. It is measured in terms of charges per mass of soil where milliequivalent (meq) is the number of charges and a 100 grams of soil is the mass. Soil particles vary widely in surface area and it is not surprising to find large differences in soils' CEC's depending upon the particle constitutions.

Humus has the highest CEC of soil particles, but the total content in soils is often very low. The 2:1 clay particles consist of two platelets of silicates and one of aluminum hydroxide. And, the 1:1 clays have one platelet of each. The platelets are joined by chemical bonds in such a way that the electronegative sites on either side of each platelate may be accessible to cations in the soil solution. The 2:1 clays have more surface area per soil volume; consequently, they have more CEC than 1:1 clays. Examples of the CEC of various soil particles are as follows:

Type of Particle	Example	meq/100 gr
Organic	Humus	100-300
2:1 Clays	Montmorrilonite	80-120
1:1 Clays	Kaolinite	1-10

A soil's CEC depends largely upon climate. Young soils are high in 2:1 clays and have correspondingly high CEC. Weathering causes dissolution of the clays. The leaching of the silicates is more rapid than the aluminum compounds and continued weathering produces a soil predominated by 1:1 clays. The

weathering process is enhanced by hot and humid conditions such as those under which most Ferralitic soils were formed. It is not surprising that Lundgren (1978) found the average CEC of Ferralitic soils which he studied to be 16 meq/100 g.

Organic matter content can have a major impact upon the CEC of Ferralitic soils. Given the predominance of kaolinitic clays in many tropical soils, it is not unexpected that more than half of their CEC is accounted for by organic matter (Sanchez, 1976).

Percentage Base Saturation (%BS)

Base saturation percentage is the fraction of non-acidic cations on the clay exchange sites. The basic cations are generally regarded as Ca, Mg, K, and Na. The remaining or acidic fraction is predominated by free aluminum which reacts with water (hydrolyzes) to generate acidity (see Acidification).

Dr. W. S Buol, Professor of Soil Science at North Carolina State University, suggested that the measurement of the aluminum fraction would be extremely important in determining the agricultural status of the soils of the Pita region because of the strong inferences that could be made about the amount of leaching (personal communication). Sanchez (1976) noted that agricultural soils with more than 60% of the CEC occupied by free aluminum would be subject to problems of acidity and aluminum toxicity.

The Ferralitic soil classification is from the ORSTOM nomenclature which is widely used in French-speaking West Africa. The ORSTOM system has the practical advantage of making the base status distinction at the highest categorical level (Sanchez, 1976). For that reason it is the primary point of reference in this study. Ferralitic soils correspond to most Ultisols, and Oxisols and some Alfisols in the USDA system (Sanchez, 1976; Lundgren,1978).

Summary of the Pedogeneis of Ferralitic Soils

In summary, the weathering process involved in the genesis of Ferralitic soils such as those found in the Pita region is generally intensive and often results in extensive leaching of bases, an enrichment of aluminum, and loss of CEC. The more weatherable base cations are leached from the top horizon leaving the topsoil predominated by acid-generating aluminum (and iron). Aluminum enrichment appears to be especially pronounced under an impoverished vegetative cover.

Weathering also facilitates the dissolution of 2:1 clays. Silicates are leached more rapidly than aluminum and a predominance of 1:1 clay and amorphous particles develops under hot and humid climates such as that of the Pita region. As soils loss 2:1 clays, their CEC decreases. But, addition of soil organic matter increases CEC.

Acidification

The primary plant growth problems associated with acidity are not caused by the effects of the protons attacking plant tissue , rather they are usually related to a deficiency and/or a toxicity condition occurring under acidic

conditions. Levels of exchangeable H+ above pH range 4.0 to 4.5 are not high enough to cause tissue damage, but aluminum and managanese are concentrated in the soil solution at potentially toxic levels at pH < 5.6 whereas the availability of Ca, Mg, and P are relatively low.

It is now recognized that the hydrolytic reaction of aluminum and iron with soil water is the primary factor in the production and control of soil acidity (Bohn,1979; Tisdale, 1975). Aluminum is generally the predominate cation and its reaction effectively buffers that of the iron (Russell, 1973). Free aluminum combines with soil water to produce protons until the aluminum precipitates as gibbsite:

Al (+3)	+	HOH	---->	Al(OH) (+2)	+	H (+)
Al(OH) (+2)	+	HOH	---->	Al(OH)2 (+)	+	H (+)
Al(OH)2 (+)	+	HOH	---->	Al(OH)3	+	H (+)

Free aluminum, which is often present in large quantities in Ultisols and Oxisols, appears to affect root growth (Barber, 1984) as well as cause acidity. The primary symptons of aluminum toxicity are thick, stunted roots and poorly developed root hairs. The effects vary with plant species, but concentrations of 1 ppm and aluminum saturation of 60 percent are considered potentially toxic levels (Sanchez, 1976; Buol, 1973). Free aluminum levels can be reduced to increasing pH to the 5.6-5.8 range where it would precipitate as gibbsite [Al(OH)3]. Or, studies show that organic matter can fix free aluminum and iron into soluble forms thereby removing it as a source of acidification #9 (Sanchez, 1976).

Manganese, unlike aluminum, is a nutrient that is required by plants in small quantities. Problems arise when manganese solubility increases under acid conditions. It can achieve toxic concentrations at pH lower than 5.5. The toxicity symptons are generally seen on the photosynthetic areas as brown spots and uneven distribution of chlorophyll (Mengel, 1979).

Calcium availability is apparently not so much affected by acidity as acidity is a consequence of calcium having been leached from the soil. Calcium weathers rapidly relative to aluminum. In most soils, Ca is the dominant cation and it buffers the acidic effect of aluminum. In weathered soils, Al becomes predominate as Ca is leached. However, the acidic condition does not affect availability of soil Ca. Studies show that Ca is equally available to plants under either acidic conditions or more neutral conditions (Barber, 1984). Magnesium uptake, on the other hand, is reduced under acidic conditions.

Phosphorous is relatively immobile in the soil and not subject to leaching to the same extent as Ca. (Shallow-rooted grass may be an effective cycling agent for P.) In highly weathered acidic soils (pH < 5.5), much of the P is complexed with free iron or aluminum and is not readily available to plants. However, actively growing plants have relatively high P requirements and optimal growth is not achieved when much of the P is occluded by free aluminum and iron (Sanchez, 1976).

Molybdenum is a micronutrient required by all plants for conversion of nitrogen into useful forms and by Rhizobium bacteria to fix nitrogen. Unlike all other micronutrients, Mo becomes less readily available to plants as acidity increases; it appears that Mo content in the soil solution decreases with increased acidity (Barber, 1984). Studies have shown that deficiencies are highly responsive to small amounts of Mo fertilizers and the addition of less than 250 g Mo/ha would have the same effect as several tons of lime (Russell, 1973).

#10

Soil microorganisms are also affected by acidity. In acidic conditions (pH < 5.5) fungi dominate the soil microbial population whereas bacteria and actinomycetes are more favored by slightly acidic to neutral conditions (Mengel, 198-). The primary importances of fungi are in the initial breakdown of recalcitrant plant matter and in the formation of mycorrhizal associations with plant roots. Bacteria and actinomycetes are involved with symbiotic fixation of nitrogen by legumes and other species. The failure of some legumes to thrive under acidic conditions may be due to the inability of the Rhizobium symbiont to function (Mengel,198-). Bacteria also mediate the transformation of nutrients in the soil into available forms.

Amending Acidic Soils

Soil acidity can be decreased in at least two ways: (1) addition of compounds like lime which enriches the soil solution with hydroxyl ions (OH-) (Tisdale, 1975), and (2) additions of organic matter which complexes free Al and reduces the rate of hydrolysis (Sanchez, 1976).

The effect of organic matter on soil acidity can be seen in the results from soil tests at the Baring Research Station near Pita (Fig. 1 and 2). Soils from one field with two soil types and an organic matter gradient were analysed for P and acidity. Organic matter variation in this analysis can be accounted for by the previous use of the land. Farmers practiced "tapade" husbandry characterized by periodic and judicious additions of organic matter to intensively cultivated beds. Those samples with relatively high organic matter content were probably collected from former bed sites.

Fig. 1 Soil Acidity vs Soil Organic Matter Content - Hydromorphic Soils

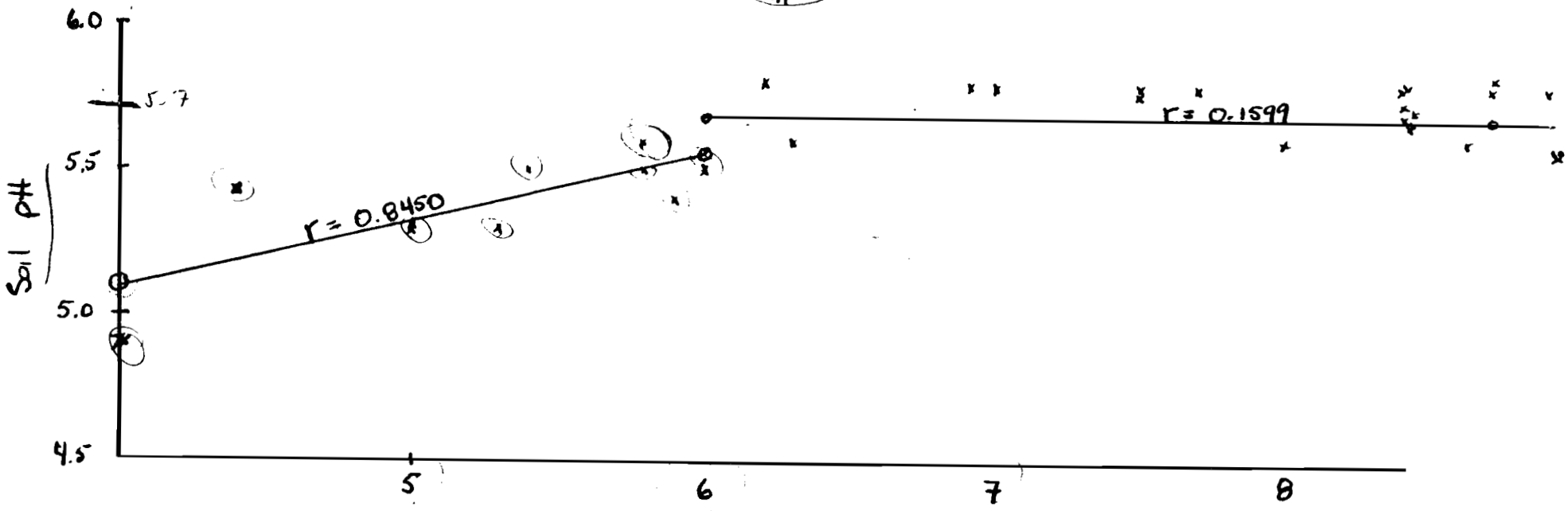

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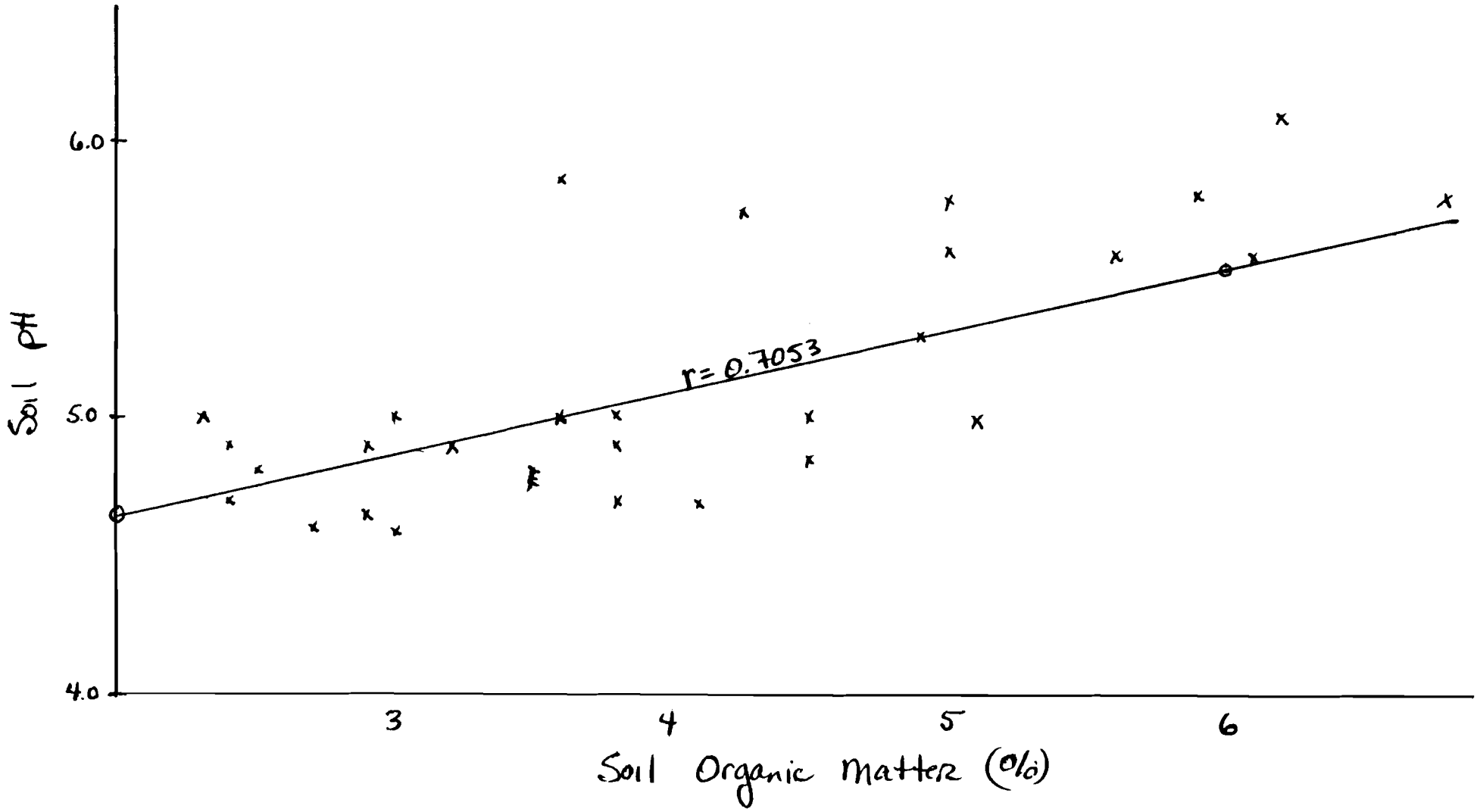
Fig. 2 Soil Acidity vs Soil Organic matter Content - Ferralitic Soils



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Soil acidity decreased with increases in organic matter in both cases. The data from the hydromorphic soils are most suggestive of a possible mechanism. Soil organic matter and pH increase up to 5.6 ($P < 0.01$). Increases in soil organic matter above the level at which pH= 5.6 produces no further increases in pH. Given that iron and aluminum precipitates at pH 5.6--5.8, the data suggest that pH increases are due to removal of free iron and aluminum by organic matter.

Laterization

Laterite is a term with numerous definitions, and the lateritic process is poorly understood given its importance for tropical agriculture. Russell (1973) reports that the term was first used in reference to the soft red earth undrlying indurated horizons, but that it now more commonly refers to the indurated layer itself or to a layer of ironstone gravel. This layer severely restricts crop growth when formed near the soil surface. In this report the term is used in the latter sense.

The rate and extent of laterization depends upon a number of factors including the soil type, climate, and vegetation. It is most commonly associated with tropical soils rich in iron. Ferralitic soils such as those found in the Pita region have a tendency to develop hardpans after intensive weathering. But susceptibility to laterization may also depend upon the vegeative soil cover (Russell, 1973).

Laterization apparently involves the accumulation of soluble iron within a horizon and its gradual crystallization into concretions. The accumulation process involves movement of free or soluble iron into areas of concentration. Movement of the free form of iron can occur in at least three ways: (1) illuviation from above as an organo-ferrous complex, (2) lateral migration as ground water solute, or (3) migration and nodulation within the same horizon (Russell, 1973).

Movement of iron is especially pronounced under waterlogged (reduced) conditions. Whereas iron is generally reddish and relatively immobile under oxidized conditions (FeIII), it is often bluish or greyish in waterlogged soils. In this state (FeII), iron is mobile in the soil solution and moves from one part of the profile to another where it may be concentrated during the dry cycle. The laterization process is completed when iron concentrations crystallyze upon oxidation.

The more rapid and extreme the wetting and drying cycles, the faster and more extensive the process. The cycles may be accentuated by removal of soil cover. The matrix of root and soil organic matter associated with a vegetative blanket buffers against rapid fluxes in soil mosture. And, the process may not be completely irreversible; studies suggest that reestablishment of vegetation may cause dissolution of laterite (Russell, 1973). To the extent that this is true, soil vegetation management by small-holders can influence soil depth. #12

Laterization (formation of indurated iron beds) may be occurring at an accelerated rate in the Pita region, but we may also be seeing the positive effects of vegetation on the process. In comparison of profiles of pits from the same sites, soils having perennial vegetation as a blanket invariably had deeper profiles. It is recognized that poor plant cover could be the result of a shallow soil and not the cause of it. However, examininations on sites where reforestation has taken place within the last twenty-five years support the thesis that plant cover can affect the laterization process over the short as well as the long term. See Pit Profiles in the appendix: compare the depth of soils in the pits on sites III, V, VII and XI.

Summary of Characteristics of the Pita Soils

The Ferralitic soils of the Pita region have characteristics similiar to the "typical" humid tropical soil as outlined by Lundgren (1978);

(1) Nutrient reserves are low;

(2) Nutrient retention depends to a large extent on soil organic matter;

(3) Organic levels decline rapidly following clearing of vegetation;

(4) Clearing and burning produces a large and rapid release of highly mobile minerals;

(5) Nutrients are leached rapidly in absence of dense root systems.

And, the additional characteristics complete the summary:

(6) Topsoils have become acidic through the progressive enrichment of aluminum and iron;

(7) Plant growth may be restricted by toxicities and/or defiencies associated with acidity; and,

(8) Raising organic matter content apparently reduces excessive soil acidity.

Food Production Systems in the Pita Region

Most food is produced in the Pita region by small-holders whose constant concern is to provide sufficient food for their families. At present the Pita region small-holder is having an increasingly difficult time meeting subsistent needs. Grain yields are low and declining, and food supplies are often low between harvests. Thus, given the small margin between sufficiency and want, it is not surprising that farming strategies are conspicuous in their absence

of risk. Capital generated from the farm is generally incidental; certainly it is not sufficiently reliable to support the gambles involved in modernization. Typically, the occasional crop surplus is often traded for rice, another staple.

The agricultural future of the Pita region is at risk. But the small-holders are not in a position to accept unknown technologies even though they have been successful elsewhere. Before they will change their practices, they will have to see a functioning agricultural system that provides (1) more reliable yields and (2) higher yields. The first reason is more important to the small-holder than the second.

Fonio (Digitaria exilis) culture is one of two principal dryland husbandries practiced by nearly every small-holder in the Pita region. The other is the polycultural "tapade." Fonio is cultivated as a monoculture during the rainy season (May-Nov) on family farms of several hectares. Tapades are intensively worked crop beds practiced on several hundred square meters within the perimeter of the family compound.

Fonio is a shallow-rooted grass that grows on soils too impoverished in nutrients and too acidic for higher yielding grains (Irvine, 1954). It is a small grain related to the ubiquitious crabgrass of temperate climes. The straw is harvested with the seed head and removed from the field. Once the seed is separated, the straw is fed to cattle or put onto tapade beds. It is generally not returned to the fields.

Fonio production is associated with acidic and impoverished soils in the Pita region. It would seem that fonio cultivation contributes to soil degradation in three ways: (1) the shallow root system mines the basic cations from the topsoil without returning the same from the lower horizons; (2) the plant matter in the straw that would normally increase the organic matter

content and help reduce free aluminum is removed, and (3) the protective vegetative cover is much reduced. The result is an enrichment of aluminum, a reduction of plant nutrients in the topsoil, and an increase in erosion and leaching of basic cations.

Some agronomist in Guinea have noted that fonio fields tend to become sandier. Over the long term, it is conceivable that reduced ground cover permits more rapid leaching of clay from the top horizon. Moreover, increased acidity would intensify attacks on the clay minerals and speed their dissolution. The consequences of reduced clay content would be degradation of soil structure, reduced cation-exchange capacity and decreased water-holding capacity.

The primary manifestations of soil degradation associated with current fonio production practices are the reduced yields and shortened fallow periods. Surveys of farmers and officials in the Pita region indicated that current yields are 200-300 kg grain/ha whereas 500-600 kg/ha is the average given as having been harvested less than a generation ago. The traditional fallow ranged from 9-15 years, but current fallows were often reported to be less than half that period.

The farmers respond to the reduced yields by shortening the fallow period. They must produce sufficient grain to feed their family, but new arable land is increasingly rare. Those who enlarge their farms in order to lengthen the fallow rotation often do so by clearing steep hills which rapidly erode, and which have little potential for long term production. As an example of the trend found in soil productivity, it was reported this year (1984) that fonio production in the Pita region would be up from last year. But, the increase would come through the cultivation of more land; yields were actually expected to be down from previous years. <u>In effect, the small-holders are in a position where they are forced to mine their farmland in order to feed their families.</u>

The tapade system represents a second system of food production in the Pita region. It is non-irrigated garden husbandry practiced on the same soils as fonio husbandry, but it involves a more intensive treatment of the soil. Beds are established within the confines of the compound and the cultivated surface may cover up to a thousand square meters. Polyculture and relay cropping characterize this system. One bed may contain several of the following crops: corn, manioc, taro, peanuts, beans, gumbo, sweet potato, squash, tomatoes, or eggplants. Fruit trees are often found on the perimeter or scattered throughout the compound area. Cultivation of the beds by small-holding families is generally continuous throughout the year, and plantings are staggered so that beds contain several crops at various stages of growth and development. For example, in a corn, taro, and manioc rotation, corn is harvested as taro reaches a stage requiring more sunlight. Taro spreads out and reduces weeds and erosion. Manioc is harvested after taro to complete the cycle.

The continual productivity of the tapade system is sustained by husbandry that maintains high levels of soil organic matter. Weeds and plant litter from the beds are turned back into the soil. Straw, animal manure, household wastes, and cooking fire ashes are brought to the beds for incorporation. Legumes are often included in the rotation. Animals do not often browse the beds, but small-holders may tether the animals within the concession to browse grassy borders and provide themselves with a convenient source of manure. Chickens feeding on insects in the beds stir the soil and add manure.

The tapades are often protected by living hedges. Not only are these hedges effective against browsing animals, they also provide dry season fodder for animals, fuelwood, and protection against the wind.

The tapade system is successful in terms of food production and maintenance of soil fertility. While productivity on fonio fields has been in progressive decline since the disappearance of virgin arable land, tapade beds have reportedly been under continual cultivation for generations. The food produced in the tapades is reportedly as important as the fonio grain. In years of shortfalls in the grain harvests, the tapades provide barter to procure fonio or rice. Moreover, tapade harvesting continues throughout the year which provides a buffer against periodic food shortages associated with monoculture husbandry. Finally, the vegetables and fruit from the tapades provide important diversity in diet for the small-holding family.

The tapade systgem has demonstrated two facts about the productivity of the soils of the Pita region: (1) husbandry that includes continual incorporation of organic matter into the soil permits sustained yields without loss of fertility and (2) integrated management of resources increases the soil's productive capacity. In that small-holders practice the tapade and fonio husbandries on the same Ferralitic soils of the Pita region, comparison of the output of both systems offer instructive suggestions as to how best to sustain productivity and reliable harvests from these soils during periods of demographic pressure and land scarcity. #13

Fuelwood Resources of the Pita Region

Fuelwood is rapidly becoming scarce. Annual per capita consumption is roughly reckoned to be one cubic meter (Cerney, 1982; LaFramboise, 1984). Fuel procurement requires that villagers walk progressively farther and that town families pay more of their income on wood (LaFramboise, 1984). Moreover, as the population grows, fuelwood is harvested at increasing rates for brick and bread making. Thus, while precise figures on forest production in the Pita region were not found, the increased difficulty of obtaining wood indicates that the demand has surpassed the production rates. (See appendix for list of species which are observed to be rapidly dissapearing from the region.)

Forests and fallowed land are the firelwood reserves, but they are become increasingly less capable of meeting the fuel needs of the population. Forested land has diminished in recent years and increased control over exploitation of the remaining classified forests has reduced access to wood cutters. Shrubby fallows provide some fuel, but they also furnish fencing material and pasture, the harvest of which depletes fuelwood reserves. Moreover, with increased cultivation pressure shortening the soil's period of rest, woody fallows are progressively giving way to grass dominated fallows. Finally, fuelwood reserves are being extensively reduced by brush fires. To halt this decline, small-holders and the GOG Forestry Service (and other technical Services) must join forces to establish a system of stewardship over fuelwood resources. This system would not only maintain the present reserves but create new sources that would be managed by the small-holders themselves to provide a sustained yield of fuel.

The Pita Community Forestry Project was initiated primarily as a response to the diminishing fuelwood supplies. But, inherent in the design was the recognition that interplanting other crops with fuelwood would provide food and forage as well as fuel, and it would enhance the soil-building process. As outlined in the mid-term evaluation of this project, the purpose of this thirty-month project is "to develop a technically sound, culturally appropriate, economically feasible and easily accessible set of innovations to provide villagers of the Pita region with fast-growing trees for fuelwood, forage, soil enrichment, and erosion control" (AAO/Conakry, 1984). Moreover, it was further anticipated at the midterm evaluation that "during the remaining time, the project will emphasize agro-forestry techniques to increase food production [by] the small-holder in the project area."

The second important aspect of the project is its emphasis on self-help. Wide-spread stewardship of the forest resources will require recognition on the part of the small-holder that the quality of his families life depends upon rational exploitation and conservation of those resources. Participation in the Community Forestry Project will provide small-holders the experience of benefitting from the establishment of village forests. If the community firewood plantation is properly managed it will be a reliable and convenient source of fuel. Ideally, these plantations will serve as models to other villages and to individuals, and the practice of stewardship can be extended as it must be if the quality of life is to be maintained for the Pita region small-holder.

This project, which is under the direction of the GOG Forestry Service and supported by USAID, is an appropriate response to the food, fuelwood and pasture concerns of the small-holder in the Pita region. If the project continues until the first harvest, the village plantations will provide a model

that will allow the small-holder to decide for himself the merits of fuelwood cropping. Moreover, increasing the emphasis on food and pasture crops within the plantation would showcase the benefits of multi-cropping.

The weakness of the design is the project length. The project managers will have three planting seasons to establish village plantations. That is insufficient time to harvest a fuelwood crop or to properly intercrop pasture or food crops. Few, if any development strategies would be adopted by small-holders without hard evidence of the effectiveness of the strategy. This consideration is too often ignored. In this case, the project should be supported until the first harvest and distribution of fuelwood. And it would have maximum impact if the means were expanded to allow integration of pasture and food crops. On the other hand, failure to manage the project until the first harvest will probably ensure loss of the progress and investment made in providing the small-holder with a means to improve his lot.

At the time of this investigation, the project under the co-direction of M. Sangare of the GOG Forestry Service and David LaFramboise of U.S.A.I.D., was at the end of the second planting season. The fuelwood plantation objectives had been accomplished despite vagaries of logistics and weather, and several progressive small-holders have shown interest in establishing their plantations.

Three nurseries have produced seedlings for forests in thirty villages. Each nursery is supervised by one GOG forester and manned by two GOG laborers. The local governments provide the nursery site and USAID provides tools and materials and the assistance of one US Forester. Cooperating villages provide land and labor for tree-planting. Seedlings are delivered in a small Jeeps from the nurseries to the plantations where farmers under the superision of the

project staff. Farmers are also responsible for laying out the field prior to planting and erecting a field perimeter fence after planting.

The principle fuelwood species transplanted into the village forests are Gmelina arborea, Cassia siamea and Eucalyptus robusta. Leucaena leucocephala was introduced this year as a combination fuel and browse species. The survival rate on the fields visited during the investigation ranged between 50 and 80%. The primary problems were untimely drought periods during August, animal damage, weed competition, and acidic soils. Relative to other forestry projects in West Africa and to the means provided, the survival rates are impressive.

The Leucaena offers the soil-building promise of a legume as well as the browse and fuel benefits. Leucaena plants in village plantations were not thriving relative to one growing next to David LaFramboise's house. It was not possible to determine whether the lack of growth in the plantation was due to soil conditions, overgrazing or both. Aluminum toxicity was implicated by the paucity of hair roots, but the tops had been browsed heavily as well. In contrast, the Leucaena plant growing next to LaFramboise's house in Pita was planted last year, and it is now over three meters in height and a copious producer of fruit. It has been protected from goats and the soil has been buffered by the concrete remaining in the soil following the construction of the house. It appears that Leucaena would benefit from protection and from a buffered soil condition.

A further problem posed by acidic conditions in the soil is the failure of Leucaena's Rhizobium to thrive. Bacteria generally do poorly in acidic soils. For one thing, Rhizobium requires relatively high quantities of Mo for the enzymatic reduction of N gas to forms available to plants. Molybdenum is less avialable under acidic conditions. Alkaline-exuding strains of Rhizobium were

procured (Mr. Michael Benge, S&T/Agr.; AID, Wash. D.C., 20523) and will be used during the next planting season. If the innoculated Leaucaena is protected from browsing, its relative growth rate should indicate whether we are seeing a plant or Rhizobium problem.

The major technical shortcomings of the project are lack of protection from animals and weed competition. However, these problems are not major when viewed from the overall perspective of the project. The entire project has six paid laborers and a field staff of five. Farmers participate in this project without compelling tangible evidence that they will benefit from their labor. Moreover, they are naturally suspicious of losing the control of land as it is put into tree plantations.

Recent occurences in other reforestation programs in the Pita region would confirm the farmers' suspicions. Under a watershed protection program (discussed in a later section), some grain fields have been summarily plowed and planted into trees. The farmer had little to say in most cases, and few perceive themselves as a beneficiary of the plantings. Naturally, few farmers in the Pita region are spontaneously disposed toward establishing a forest that may give others control of the land. In spite of these natural reservations generated by other programs, the farmers participating in the Community Forestry Project have maintained interest in the trees and the strategy of the project.

Planting and managing a fuelwood crop is a novel concept in the Pita region, and there is no model to provide the small-holder with a compelling reason to adopt it. With that perspective, the progress made to date in demonstrating the fuelwood lot strategy is remarkable. The design of the project has aided in this success. In contrast to the watershed reforestation project in the Pita region, which has a mandate to plant as much land as

possible to protect watersheds, the Community Forestry Project has concentrated its efforts on establishing models which will serve to demonstrate the benefits of fuelwood production and to produce multiplier effects.

The high take rate in the project suggests that planting was done conscientiously. Fences were built around most plantations, and even though some need repairs, the amount of work involved was not trivial. It appears that farmers are willing to plant and protect fuelwood trees if the seedlings are provided. Proof of the 'new' willingness was seen in the theft of about 1,000 seedlings from one of the project nurseries.

Other positive signs of interest are seen in the desire of one village to establish a village-owned and operated nursery. One individual plans to establish a private nursery as well as fuelwood lot. This individual is an innovative and progressive small-holder who is seen as a model by other farmers in the area. He will be discussed in more detail in the the last segment of this section.

Additional reasons for the success have been the resourefulness and tenacity of the Project Co-Directors, Messieurs Sangare and LaFramboise. These qualities have been well displayed in procuring fuel and keeping the U.S.-Jeep in service. A breakdown or shortage of fuel during critical periods such as planting season would put the whole year in jeopardy. Fuel is often scarce and the Jeep requires a lot of attention relative to the more ruggedly-built Toyotas and Land Rovers used for similiar work in the Pita region. There are virtually no source of spare Jeep parts in the country, and even simple repairs have the maddening requirement of special tools "available only at authorized Jeep dealers." Thus, time that would otherwise be spent on village forestry is by necessity contributed to pulling bearings with makeshift tools or repairing the disposable plastic gas tank.

The field staff receives excellent support from the USAID mission in Conakry. Cognizant of the difficulty of spare parts, the Conakry office expediates their shipment. Moreover, the excellent relations between the GOG Forestry Service and USAID at the top level facilitates project coordination.

In summary, good progress has been made in achieving the goals of the Project. The staff possesses a can-do attitude rather than laying back upon a list of why things will not work. This project should be extended and the emphasis expanded to pasture and food crops. The present staff should be kept intact to the degree possible. This is an excellent opportunity to provide a multi-crop model to small-holders. The model would provide small-holders the opportunity to make their own decision about the advantages integrating food, fuel and pasture crops on one plantation.

Pastoral Systems on the Fouta-Djalon Plateau

Pasture is produced on the same land that is cultivated for fonio production or that supports trees and shrubs which are cut for fuel. Overgrazing is detrimental to all three resources. It promotes soil erosion, and fuelwood species may be browsed to the point where they are unable to coppice. However, properly managed pastures can be complementary to food and fuel production and to soil rebuilding.

Dr. I. S. Bah (1976) studied the possibilities of natural pasture improvement in the Dalaba region for his thesis at the Institut Polytechnique Gamal Abdel Nasser de Conakry. The region which he studied was on the southern edge of the Fouta-Djalon plateau. The conditions are similiar to the Pita region, which borders the Dalaba district to the north. His study was relevant

to this study in that it provided essential information on the natural pasture resources and on the pastoral practices. This section is essentially an outline of the relevant parts of his thesis. The pastoral plants which he covered are presented in the appendix of this report.

Bah reports that animal husbandry rates with agriculture as one of two principle segments of the economy. Traditional husbandry is extensive. Cattle are first considered a symbol of status and prestige and only secondarily as a source of revenue. Consequently, herd quality is often less important than size to herders.

The pastoral system is characterized by free pasture use and transhumance. During the rainy season, animals graze close to the owner's compounds. While some attempt is made to keep animals from fonio fields, conflicts often arise over animal damage. Animals which are tethered near the compound during the rainy season often ruin the pasture. They trample much of the grass and compact the soil. The young sprouts of the preferred species are continually grazed and the plants do not have the opportunity to build up reserves. In this way some of the best species are lost.

Transhumance to wetter sites is often practiced during the dry season as the annual grasses disappear. Transhumance becomes more frequent and longer as the woody perennials disappear from sites. Burning of perennial grass pastures is often done to promote regeneration of overgrazed or senescent pasture plants. Plants which are burnt indeed produce a short flush after burning and this provides some additional pasture. However, burning like overgrazing saps the reserves of the grasses and consequently impoverishes subsequent pastures.

Bah separates the region into two important soil types with respect to pastoral vegetation. Ferralitic soils are found on the plateaux and hillsides and are seasonally wet or dry. They are primarily used for fonio production. The fallowed land is generally predominated by grass and shrub, but pockets of trees may be found. The principle pasture plants associated with the Ferralitic soils are Parkia biglobosa, Cassia sieberiana, Pennisetum spp., Rottboella exalata, and Andropogon spp. Hydormorphic soils are humid and often found to be wet during the dry season. They often support permanent pasture and large trees. Andropogan gayanus, Panicum maximum, Ficus spp., and Alcornea cordifolia are pasture species often found on these soils.

Bah reports that a more specific classification of pastures can be made according to their soil moisture status. Pastures are classified by herders as to the time of year that they are productive.

1. Sedhirgo: pastures along waterways. They are used during the dry season (Jan.-May). Predominate species include Pennisetum and Panicum.

2. Settirgo: hillside pastures that support Hyparhenia during the early part of the rainy season (May-July).

3. Rumirgo: Mountain and plateau pastures supporting Pennisetum and Dicetomas fastigiata during the heart of the rainy season (July-Sept).

4. Dabbirgo: Skeletal and lateritic plateaux which are used at the end of the rainy season and first part of the dry season (Oct.-Dec.). These shallow soils support grasses, Loudotia spp, and Diectomis fastigiata.

Bah states that the most important factor for improved animal production is a reliable supply of fodder. Moreover, the pasture constitution should be upgraded. The addition of legumes would be a major improvement. It is well known that the carbon to nitrogen ratio is much lower in legumes than in

grasses. Felker (1978) notes that the leaves of leguminous trees have a C:N ratio of about 16:1 while the ratio is nearer to 80:1 in grasses. To quote from Dr. Bah's thesis, "The principle characteristic of tropical pastures is the rarety and often the absence of leguminous plants which, under a small volume provides a large part of the proteins necessary for the production of healthy offspring, the growth of the young and the production of milk."

However, it is important to note that an attitude change is necessary if pasture management is to become a common practice. In a nutshell, the potential for an improvement in animal production depends as much on changing common attitudes toward herd management as it does on pasture improvement. Brush fires will have to be reduced, and overgrazing will have to be stopped. Animal grazing will have to be controled by the owners. It should be noted that market conditions for animal products will have to improve to provide small-holders with an incentive sufficient to break generations of tradition. And, new pasture models that reverse the trend of disappearing woody fallows will have to be provided.

Fallows in the Pita Region: Multi-Purpose Reserves

The fallow period is generally associated with regeneration of the farmland's productive capacity. In the the small-holder's environment, he is concerned with the soil-building quality of the vegetative blanket as well as its effectiveness in supplying basic necessities such as fuel, fodder, construction material, fruit and medicine.

The regenerative capacity of a fallow and the productive capacity of the soil are inextricably joined in the Pita region. The relationship can be seen as a circle wherein each is a function of the other and the overuse of either will break the circle. The consequences of a break are impoverishment of the fallow products and lengthening periods of fallow required for soil regeneration.

Effects of Fallow Vegetation on Tropical Soils

This study may have been sub-titled " The Effects of Vegetation of the Soil". Soil studies done in many temperate zones are often done with respect to amending the soil to accomodate a particular crop. When manufactured products are not available, the vegetation covering the soil is the primary soil building agent. Given the dependence of the Pita region small-holder on the fallow vegetation to rebuild his farmland, he has a keen interest in establishing the most accomodating soil cover.

The plants that constitute the fallow should pump leached nutrients to the topsoil, increase organic matter content, and protect against erosion. Moreover, the constitution of the fallow should contain a diversity of species that supply fuel, pasture, construction materials, edible fruits and indigenous medicines.

Nutrient cycling in the Pita region. Ferralitic soils as found on Pita farmland are subject to intensive leaching of bases and enrichment of aluminum and iron. Grain yield potential has decreased and the genesis of acidic soils has accelerated. Effective fallow species must mine the lower horizons for Ca, Mg, and K and return the leached nutrients to the topsoil. The addition of these elements to the topsoil would increase base saturation and reduce the genesis of acidity.

Fig 3 EFFECTS OF FALLOW Vegetation on Pita Soils - Ferralitic Soils

Available P vs Organic Matter Content

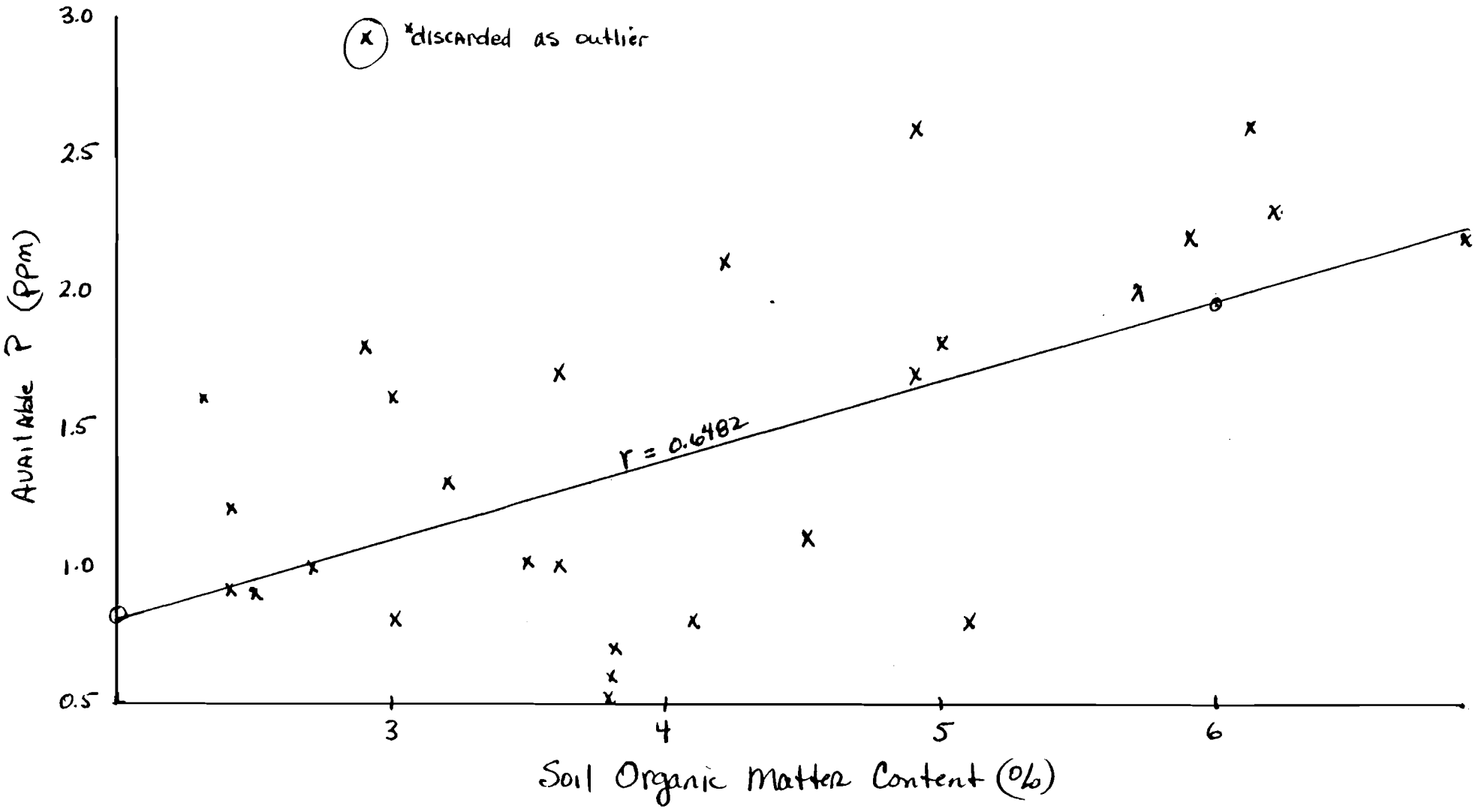
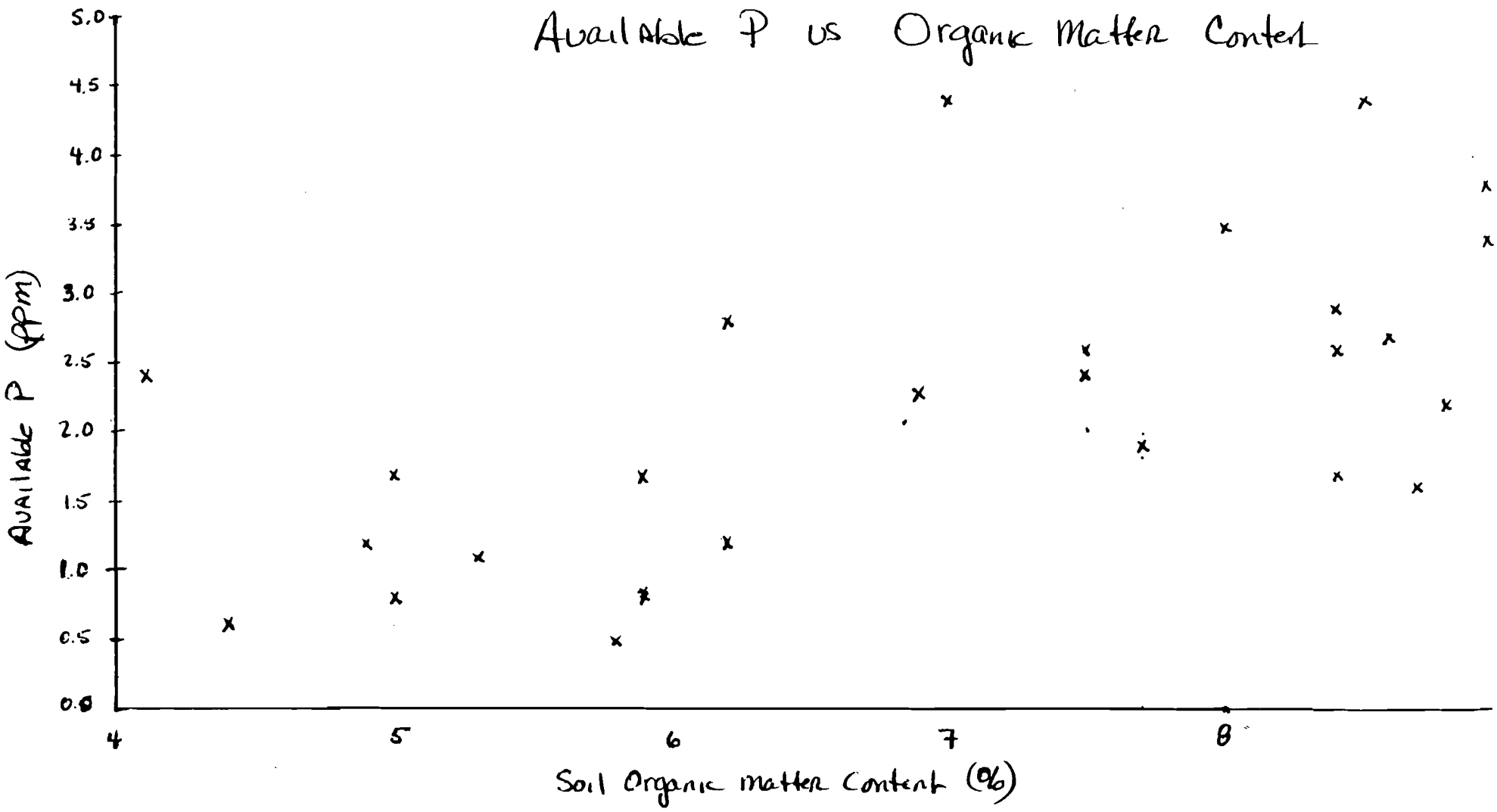


Fig 4 EFFECTS OF FALLOW Vegetation On Pita Soils - Hydromorphic Soils

Fig 2



Soil organic matter. Soil vegetation not only works to cycle nutrients, it also provides organic matter which has manifold roles in maintaining soil productivity. Soil organic matter fuels the microbial population, acts as a plant nutrient reservoir, impoves soil structure, increases CEC and buffers acidity.

The biogenesis of organic matter from plant litter begins with recognizable plant parts and finishes with carbon dioxide gas. The degradation process includes the formation of a number of organic products which provide manifold benefits. For one, the soil flora and fauna necessary for a productive soil require organic matter for energy and growth. Various organisms extract energy from the organic material at each stage of degradation. In return, the microorganisms degrade the organic matter, and nutrients fixed in the organic matrix are released into the soil solution in plant-available forms.

Organic matter often serves as the major reservoir of plant nutrients in weathered soils as found in the Pita region. Studies cited by Buol (1973) show that in weathered soils as found in the Pita region, pratically all of the nutrients in the natural ecosystem are within living or dead plant tissue. The levels of exchangeable basic cations and available P in the top soil were found to be a function of the density and size of the vegetation on the soil. The gradual release of the nutrients from the organic reservoir protects them from leaching.

The degradation process enriches the soil with recalcitrant products such as humus, which, like microbial exudants enhance soil aggregation and soil cation exchange capacity. Humus is a large and complex molecule which carries numerous excahnge sites (Lynch, 1979). These sites may account for a major portion of CEC in soils predominated by 1:1 clays and sesquioxides (Russell, 1973). Thus, on many Pita soils low in organic matter leaching is a major

problem. If the soils of the Pita region are enriched by manufactured fertilizers, the soil is so naturally low in CEC that it will require substantial organic matter to hold those expensive nutrients against excessive leaching.

These sites on humus also form a bridge between soil particles that improves the structure. Moreover, it is thought that the ability of organic matter to reduce excessive acidity is by virtue of the high charge density which would complex aluminim and iron.

It is quite clear that soil organic matter is extremely important to the condition of weathered agricultural soils. This is the case whether under subsistent or capital intensive husbandry. The type of fallow vegetation is extremely important in building and maintaining adequate levels of soil organic matter. As will be discussed later, a vegetative blanket predominated by trees and shrubs is the most effective means in the tropics.

Protection of the water and soil resources. The climatic vagaries and rolling topography of the Pita region enhance water erosion. Rainfall events are often intensive. When the soil is unprotected and/or crusted, infiltration is reduced and much of the rainwater moves on top of the soil carrying soil particles. Removal of topsoil has serious consequences in the Pita region. Many soils are underlain by an indurated bed. Soil productivity is often a function of the depth of soil over the beds. Evidence of soil erosion could be seen from the soil pits. The colluvial soils of the lower pits or poorly covered hills were often deep, whereas soils of the upper pits were shallow, approaching the skeletal classification. See Pit Profiles in the appendix: compare pits on site numbers I and II.

Soil moves when water velocity is sufficient to move the aggregates. Poorly aggregated clay is the most susceptible to movement by water. Silt is the next to be carried away and sand is the last to be moved. Unfortunately for Pita farmers, clay carries relatively high cation exchange charges which is important to protect Ca, Mg, and K from leaching. These elements may be lost to the topsoil as the clay is carried away.

The velocity of the water must be slowed to decrease erosion. The infiltration rate is one control factor. Soil aggregates that receive the full impact of the raindrop are more likely to be broken into small pieces that are washed into the pores of the topsoil. Infiltration rate decreases as the pores become clogged. The soil forms a crust under such conditions and water begins to move along the top of the soil. The smaller pieces of soil are carried by the water. If the soil was resting on a slope of a hillside, the eroding process is exagerated.

Any strategy to reduce erosion must include ways to (1) improve soil aggregation to reduce destruction by the impact of raindrops, (2) reduce the velocity of the raindrop, and (3) reduce the slope. Organic matter provides the binding material to improve aggregation (see the discussion in the value of soil organic matter.) Ground cover absorbs the energy of the raindrops and spreads out the time during which the water collects over a given area of ground. Grass serves this purpose well during the mid to late rainy season but perennials are required during the early rainy season when intensive rain storms are common. The slope of the entire hillside can not be changed but vulnerable points can be terraced.

Soil movement on poorly covered fallows has consequences beyond loss of arable land. Silted-in watersheds pose a serious threat to the hydroelectric system of the Pita region. The reservoir behind the Kinkon dam near Pita is

filling up rapidly. Power production is no longer available during the dry season and has become less reliable during part of the rainy season due to the reduced head behind the dam. Certainly, future industrial growth is limited by this declining power supply.

In recognition of the consequences of erosion, FAO has launched a major watershed reforestation program. Progress has been made, but the eroding area is vast and growing, and one centralized project would best reduce the problem by promoting farmer participation. But, farmers do not presently perceive a direct benefit from watershed management. Moreover, some grain fields are summarily plowed into tree plantations, and farmers lose control over their land. Thus, the potential of a multiplier-effect is lost by lack of compelling evidence to farmers that reforestation of their lands bordering watersheds would provide them with tangible benefits (fuel, pastures, etc.).

Fallows as reserves of daily necessities. Fallowed land is a major source of fuel, pasture, construction material, and medicinal plants. Forests traditionally supply many of these necessities, but their size and access are being reduced by farmland and grazing pressure, fires, and stricter controls by the Forestry Service.

Shrubs and trees supply high quality fodder for growing animal herds. Maronai (*Albizia gumifera*), Nonko (*Ficus bougouanouensis*), and Bani (Terracarpa spp) are trees bearing foliage which is sought by herders for browse during the dry season. Moreover, the leaves of the woody perennials often have a high content of essential nutrients relative to grasses. Evidence for animal's preference for leaves of woody plants over grasses was observed during the investigation. Cattle sought out the foliage of trees and bamboo (a perennial grass) despite the fact that grasses were still lush and vigorous from summer rains.

Construction material for fences comes primarily from shrubby fallows. Each year a farmer may fence off a few meters to several hundred meters of his grain field or tapade. Young saplings in fallowed areas are harvested as perimeter fence material. Termite attacks and weathering usually limit the service of the "stick" fences to one year and the harvesting of shrubs is annually repeated. However, if the farmer has access to cuttings from one or more species that serve as living hedges (Sisal, Ficus spp, Lammia, etc.), he may bed able to reduce the quantity of saplings harvested. But, the supply of living hedge species is often limited and the depletion of woody fallows will probably continue as farming and grazing pressure continues.

Indigenous medicines are an important part of everyday life, and the population of Pita depends upon forests and woody fallows as reserves for medicinal plants. Some of these plants are noted in the thesis of Dr. I. S. Bah (1976). As fallows deteriorate, the likelihood increases that important medicinal plants would become scarce.

Genesis and Consequences of Degraded Fallows

The maintenance of soil productivity under traditional husbandry requires an equilibrium between the cultivation of the soil and the rebuilding fallow period. The length of that period depends upon the soil fertility level prior to the fallow, and upon the plant constitution during the fallow period. A shortened fallow period or a fallow dominated by shallow-rooted annuals will be less effective in enriching the topsoil in organic matter and plant nutrients. However, as indicated previously, at the very time that declining yields would require longer periods of fallow to rebuild the soil, demographic pressure necessitates increased harvests of food, pasture, and fuelwood. But, little, if any, arable land is left to clear in the Pita region. Thus, we see

developing a paradox with grave consequences for the small-holder in the Pita region: truncated fallow periods necessitated by increasing pressure are progressively accompanied by loss of perennial ground cover which would otherwise compensate for the shorter period.

The extent of the soil degradation in the Pita area was discussed earlier in terms of the decline of fonio yields. It was also noted during the investigation that dryland rice was once part of the monoculture rotation, but it is rarely grown in the Pita region except on humid, colluvial soils which have been enriched by erosion. What we are seeing is the genesis of an ineffective fallow rotation and the progressive decline of the soil's productivity. Without adoption of an appropriate strategy, the Pita farmer is locked into a system that ensures the eventual loss of his capability to feed his family.

Field and Brush Fires

Extensive use is made of fire to clear fields, to force regeneration of pasture grasses, and to produce ash. Little effort is made to contain the fires and extensive areas of grass and shrub land of the Fouta-Djalon are burned every dry season (Nov - April).

The brush and field fires provide manifold consequences; some provide ephemereal benefit, but all pave the road to loss of soil productivity. Some perennial grasses and shrubs produce sprouts after being burned and the young tissue provides limited forage at the expense of long-term vigor. Some farmers pile brush around trees and stumps in grain fields to destroy them and to produce ash. Piles of dried manure and straw are often burned just prior to

the rainy season for soil enrichment (the "mouki" system). Burning wood, grass, and manure provides some readily available plant nutrients, but they are highly leachable and may be removed from the profile with percolating water. And, most of the nitrogen and sulfur in the plant matter is lost as gas during combustion.

Moreover, the oxidation of the carbon in the plant tissue and manure reduces the potential soil organic matter which would have increased the nutrient reservoir, increased the cation exchange capacity, buffered acidity, and enhanced soil aggregation. An additional legacy of the annual brush fires is the depletion of the vegetative blankets and increased erosion.

It is believed by many that burning impoverishes the soil's microbiological activity. It is not likely that the temperature of fires would destroy significant portions of the microbial population (Russell, 1973), but the loss of soil carbon and other elements reduce the population's nutrient reserve. Given the important roles of the soil microbial population, the reduction of its activity would have serious agronomic consequences. Soil microorganisms mediate the transformation of plant nutrients in the soil to available forms. They also fix nitrogen gas into a form that plants can use. And, they exude waste products that improve soil aggregation. Thus, it is easy to see that burning the microbial food supplies would preclude optimal soil productivity and regeneration. Under the present situation, it is necessary for the small-holder to create optimal conditions for his limited resources.

The constitution of the vegetative cover during the fallow period is an #15 important factor for soil building. Contrary to temperate zones, woody perennials are the most important soil-building plants. Tropical grasses generally grow only during the rainy season, but trees and shrubs grow during the entire year and continue to cycle nutrients and produce

litter. These contrasting habits are cited as the reason that tropical soils under forested canopies have organic matter contents comparable to temperate soils despite the five-fold greater rate of organic matter decomposition found in the tropics.

Socio-Economic Constraints to Agricultural Development in the Pita Region

The priority of the small-holder in the Pita region is to provide sufficient food for the farm family. And, he generally does this on a harvest to harvest basis. Reliable harvests are essential. Under the pressure of this basic condition, the small-holder does not have the luxury to consider the long-range consequences of his practices or to use strategies that involve risk of harvests insufficient to feed his family. Without compelling evidence that a new strategy will provide harvests as reliably as familiar practices, the farmer cannot afford to adopt a new strategy even though it has proven itself superior elsewhere. Thus, the successful introduction of reliable, higher-yielding farming systems in the Pita region will not be accomplished without the establishment of a viable, tangible pilot or model permitting the small-holder the opportunity to convince himself that adopting a new strategy will provide higher yields, and more importantly, more reliable yields.

In the industrialized regions of Central and South America, productivity of acidic, tropical soils has been increased by intensive management of fertilizers, lime and pesticides (Sanchez, 1976). However, this progress was made on an economic infrastructure that readily generated the necessary capital to support investment. The current situation in Guinea is different, and the small-holder must face the very low probability that reliable markets will be available in the near future for capital generating commodities. Case histories of food processing enterprises in Guinea graphically underline the low probability.

Several produce processing enterprises have recently been established but none were found by this investigation to have provided a reliable market for the Guinean small-holder. Tabacco production at the Baring Research Station near Pita has stopped because the national cigarette factory in Conakry has failed to pay for previous shipments from the station. Reportedly, the factory now pays hard currency for imported tabacco even though the quality of the Pita tobacco has been deemed to be of high quality. The tomato paste factory at Mamou and the fruit processing plant at Kankan are reportedly inoperational due to lack of parts and cans.

While processing is at a standstill, fruit is found in such periodic abundance in the Pita area that much of it rots on the ground because it can not be eaten quickly enough. (It is worthy to note that the Pita region small-holder produces surpluses potential commodity crops such as fruit without capital investment. But, while these produce supplement the grain crops in the diet of the small-holder family, they do not fully substitute for the grain.)

The factors controlling the future of small-holder commodity crop production do not stop at the management of processing factories inside Guinea. The competition of the international marketplace and the capricious nature of the fertilizer industry must be recognized. Despite established canning industries in several West African countries, the most economical preserved food products found in the Pita market were from Europe and South America.

The price and supply of fetilizers have been extremely volatile over the last decade. During the petroleum shortage of 1973-75, the price of nitrogen fertilizer increased by 450% (NAS). The economic consequences of such fluctuations would be catastrophic to a small-holder. Moreover, fluctuations in the world fertilizer supplies and poor internal distribution systems would seriously hinder timely fertilizer applications by farmers.

Furthermore, the extension of information on the appropriate use of fertilizers and pesticides would require upgrading of the Guinean Extension Service. At present, the Service does not have the resources in vehicles and fuel to meet the recurrent obligations that would be necessary to ensure optimal benefits.

It is quite possible that the food processing industry will one day provide a reliable market for the small-holder and enable him to modernize. But the small-holder must make sure of his basic food and fuel needs; the past and current record precludes a capital investment strategy as part of the first approach to ensuring the most basic necessities for the small-holding family.

It has been noted that many small-holders have shown the ability to raise an abundance of commodity crops without the use of fertilizers, pesticides or machinery. Rapid modernization is a theoretically attractive means to increase productivity and improve the quality of life of the small-holder, but there appear to be few if any successful capital-intensive models that would not put his livelihood in jeopardy. Models of enterprise should be developed and extended as soon as they prove reliable. But, in the meantime, the small-holder must face the immediate problem of declining yields of staples which rarely generate capital, even in good years. To ensure his livelihood, he will need a model consisting of the tried and proven and ready for operation. (See appendix for models from other parts of West Africa.)

We will now take a look at one small-holder who has ensured his families livelihood and who is a model of enterprise through use of his own resources.

Monsieur Bary's Farm: A Case Study of a Successful Farmer

Most farming communities have individuals who consistently produce more than their peers. Most do it with natural resources no different than their neighbors. Mr. Bary is one such progressive small-holder in the Pita region who has consistently produced more than the average farmer without the assistance of outside resources. He produces abundant quantities of high grade produce with locally produced tools.

Mr. Bary represents a chronically ignored resource that should be brought to bear against the food production problems in the Pita region. Unlike imported technology, Mr. Bary's practices are proven and readily transferable to his neighbors. The identification and extension of the essential practices that make his system more productive would have a major impact on the food production capacity without a major investment.

Unfortunately, the best of the traditional systems of husbandries are often ignored or discounted in the development of of strategies for agricultural development. It is an intent of this section and a section in the appendix to examine aspects of traditional husbandries that could used in development programs.

There is no implication intended that Mr. Bary could not use the accouterments of modern agriculture to improve productivity. But, the question must be asked whether he could annually sustain the costs of fertilizer, lime,

pesticides or machinery at this time. As discussed in a previous section, farmers in the Pita region do not have well-developed markets for commodity crops which would have to be sold to purchase the above inputs. And they would be the first to be affected by the periodic shortages of fertilizer. Moreover, small-holders like Mr. Bary do not have government programs to help fund new agricultural systems or to support farmers during harvest shortfalls. There is little doubt that they will continue to feed their families on a harvest to harvest basis.

M. Bary has a diversified operation in every sense of the word. He produces fonio, has an extensive orchard and has created a nursery/garden with crops ranging from peanuts to fruit tree seedlings. Common characteristics of his operations are ground cover lasting much if not most of the year, and frequent rotations of crops.

He cultivates fonio on a steep hillside in a relatively underpopulated area of the Pita region. Thus, while he farms on slopes that would normally enhance erosion, pressure on the land is light and he maintains a high fallow: cultivation ratio. He said that he generally farms the soil for three to four years and rests it for nine years. He does not destroy the native shrubs and trees when he cultivates; he prunes the major shading limbs of the large trees (Khaya, Teli, etc.) and cuts the shrubs back above the ground. The trees and shrubs recoppice each year and maintain vigor during the cultivation rotation. He avoids the use of burning to clear land or to produce forage. Consequently, his fallowed lands had well established canopies of shrubs and trees.

M. Bary's system of fonio production is to be compared to that of other small-holders on the same type of terrain. Many use fire to destroy trees and shrubs. These farmers get short term benefits from the ash but much of it is lost in the first year (Sanchez, 1976). The long-term consequences, which have

been discussed in detail above, are increased erosion, acidification, loss of nutrient cycling and a progressive decline in productivity. Their fallows are generally sparsely populated with herbacious plants. There were no statistics on yields from M. Bary's yields, but the healthy and shrubby aspect of the fallowed fields gave testimony to the efficacity of his husbandry.

M. Bary's garden/nursery operation has the benefit of a stream which provides him with an additional resource, but extension of the practices developed by M. Bary would help nearly everyone in one way or another. For one, the Pita region has numerous small waterways, many of which are underused. (Paranthetically, it was found during the investigation that waterways were less seasonal when the region had a richer vegetative blanket.) Secondly, application of most of his practices lend themselves to the dryland tapade husbandry.

Mr. Bary formed his garden/nursery complex from a swamp. He channelled the stream into an irrigation reservoir, and he used the fill to form his beds. The beds are raised and generally intercropped. We found the following crops on these beds: gumbo, peanuts, manioc, orange tree seedlings, piment, eggplant, onion, papaya, taro, and avocato trees.

To maintain fertility, he brings in what manure he can gather and turns in green manure if termites are not too numerous. He rotates legumes and maintains some deep-rooted crops on or around most beds.

He maintains termite control by constantly stirring the termite runs, removing wood, disrupting of nests, and maintaining a high level of soil fertility. Termites have largely been kept under control even though they are common in the area. Moreover, the soil is well-humified and the plants are well nourrished which appears to provide them with some resitance to termites.

M. Bary's rotation include legumes such as peanuts. His peanuts are well nodulated but few were reddish. It may be that there are low levels of Co and Mo. Certainly these two amendments would be relatively inexpensive to import because they are required in very small amounts. (Russell [1973] cites research on tropical soils indicating that less than 300 g. Mo/ha is sufficient to ensure adequate levels.)

Mr. Bary's fruit orchard is by his house on the knoll of a hill above the stream. He raises orange, mandarin, avacado, guava, and mango trees without irrigation. Taro, pineapples, sweet potatoes, and manioc are intercropped among the fruit trees. He cultivates coffee and bananna plants farther down the hillside closer to the stream.

He has been growing fruit trees for 17 years. He started by collecting seeds around markets and planting them in a garden. He manured his trees for 17 years by hauling manure to the tree. If he sees a chlorotic tree, he feeds it with manure and plant litter. He showed us one tree with some chlorotic leaves which he has been working on. He also uses a pair of clippers received from David LaFramboise to prune diseased wood from the trees.

He markets much of his produce and fruit tree seedlings locally, but some of the fruit makes its way to Senegal. Merchants truck much of his produce from his site. He also sells orange seedlings which is innovative. Next year he will be working with Mr. LaFramboise to establish woodlot species in his

nursery (Gmelina, Neem, etc.) He will plant some for his own use and put others up for sale. This development by the Community Forestry Project, if successfully pursued, will be a remarkable step for several reasons:

(1) The private sector will have entered the reforestation business;

(2) Farmers will have demonstrated sufficient interest in fuel-wood trees to indicate a willingness to provide stewardship for non-fruit trees.

One aspect of M. Bary's operation that undoubtedly contributes to his success is lack of monoculture. The land is used intensively and material is constantly being returned to it. The polyculture assures that the whole profile of the soil is worked by roots and that a minimum of nutrients are lost. Rotating and multiple cropping means that the soil is usually covered by at least one crop and often by two or more.

The Future

Erosion control on the fonio field is a priority for M. Bary as it is for many small-holders in the Pita region. The hillside where fonio is cultivated is quite steep and the outcroppings indicate a shallow soil on parts of the hilliside. M. Bary has asked David LaFramboise to assist him in establishing erosion control plantings on the hillside . Trees would be appropriate as they would add humus at a high rate and quality. Cashew nut trees have been used successfully for hillside erosion control in some dry areas of the world. They have been grown successfully in the region and may adapt to some of the hill sites. Bushes and shrubs should be considered. Local legumes may be appropriate. A shrub pasture would be appropriate because it would provide perennial cover and provide dry season fodder. Leucaena has been used successfully in other countries as hillside plantings. Grasses provide cover during a limited period but may provide soil protection during late rainy season. Eucalyptus trees should be avoided. They tend to have very superficial root systems which discourages the establishment of other soil cover.

M. Bary should give serious consideration to the potential obligations of capital intensive programs that would burden him with debts. There is no question that M. Bary could increase productivity with pesticides to control termites and fertilizers to increase crop growth. However, the source of income necessary to purchase these items is tenuous and beyond the control of M. Bary and the other Pita region farmers: (1) he depends to a large degree upon the distant Senegalese market to sell fruit; (2) his fruit tree business puts him in direct competition with his buyers in the limited fruit market; (3) his coffee would have to go through a marketting board and compete with coastal growers; and, (4) imported products would have to be paid in some currency other than the Guinean Sylis which ties M. Bary more tightly to a foreign market for his produce. Under the present circumstances, if any or all of the markets is lost, M. Bary would lose an income but not a livelihood. Thus it remains that the remarkable aspect of M. Bary's success is that it was done without dependence upon outside inputs.

The use of biocides in the garden should be approached with caution. The sustained tilth of M. Bary's garders and orchards probably depends to a large degree upon the activities of microorganisms working on the soil organic matter. As discussed previously, tilth is a function of a healthy relationship between microbes and organic matter. Both provide important products. If pesticides affected the microbial life, soil chemical and physical properties would be adversely affected. This is not to dissuade introduction of pesticides for termite control, but trials are required to study the consequences before it would be used on a large scale.

Efforts should indeed be made to help M. Bary help himself improve his quality of life. But, to reiterate, it should not put him at risk of losing his means of providing the basic necessities for his family. If modernization

is to occur in Guinea for the small-holder, long-term market committments must be established. To date this strategy has not proven effective and years of development may be necessary to establish conditions that would not put the small-holder at perpetual risk. In the meantime, he needs proven strategies to help himself.

One appropriate strategy is the private fuelwood plantation. M. Bary's acceptance to try fuelwood cropping is a strong indicator that the concept is gaining credence in the Pita region. This is remarkable in that any plantation is several years from harvest. This interest marks a significant gain by the Project and should be capitalized upon. The resources of the project should be expanded to provide Mr. Berry and others like him with as much assistance as possible. This is an enterprise that will not require sustained outputs. Many of the species can be transplanted from bare-root stock.

M. Bary would be assisted by receiving supplies and materials that have no recurrent obligations. Some of these would be as follows:

1. Hand tools: shovels and picks for terracing and garden work.
2. Plastic pots: the cost of a pot is a small part of the worth of a a tree in the field.
3. Seedlings: provision of seedlings to someone who would provide stewardship is a small investiment with major returns with respect to the total community.
4. Living hedge cuttings: providing small-holders with a cuttings of shrubs and trees that will form living hedge will save countless other plants from being harvested as dead fencing.

5. Strategies for composting: composting is a means to concentrate nutrients from organic matter and to produce a matrix which provides soil with increased CEC, water-holding-capacity, and aggregation. Improved techniques would assist small-holders to get more from their soil as well to protect it.

6. Strategies for erosion control: erosion reduces the total area available for production. Reducing erosion also reduces the pressure on the land.

CONCLUSIONS AND RECOMMENDATIONS

Summary of Conclusions

1. The soil of the Pita region farmland is generally acidic (pH < 5.5), heavily leached of bases and low in organic matter.
2. This condition is directly related to the degradation of vegetative cover on the soil, especially the loss of deep-rooted perennials.
3. The reestablishment of perennial soil cover is required to restore productivity of farmland, but annual harvests of food, fuel and forage must continue during regeneration.
4. Use of fertilizer or lime or other strategies requiring recurrent costs is not economically feasible for the small-holder at this time.
5. Integrated management of food, fuel, and pasture crops on same land would achieve the above dual objectives.
6. The Pita Forestry Project, enlarged in scope and extended to the initial harvests would be the best vehicle to demonstrate the benefits of integrated crop management.

Expansion and Continuation of the Pita Community Forestry Project

One development program that addresses the basic needs of the small-holder is the Pita Village Firewood Project. Fuelwood scarcities have been increasingly recognized by small-holder families as being a source of hardship. Consequently, the fuelwood crop strategy being developed by the Project has attracted the attention of progressive farmers and villagers in the Pita region. This small-holder interest, which is a rare quality for development projects, should not be lost. It could well be used to promote a strategy that increases food and pasture as well as fuel.

The findings of this investigation strongly suggest that the emphasis of the Community Firewood Project be expanded to include the establishment of grasses, browse shrubs, and living hedges and that the activities be continued through the harvests of each crop. The small-holders have the resources to practice integrated crop management, but they must be assured of its effectiveness and lack of risk. Comparisons of the harvest of food, pasture, fuel, and construction materials from the integratred cropping pilot against those from current practices would provide the most compelling evidence.

The project enjoys credibility amongst the participating villages and has created genuine interest among progressive small-holders. However, it is necessary to recognize that the interest of the farmer at this point is based more on the trust that the continued presence in the field by project staff indicates the worthwhileness of the fuelwood crop strategy. Without evidence of more reliable grain harvests, a profit, or a reduction in fuel shortage, few farmers will find compelling reasons to adopt the strategy. The successful extension of this integrated crop management strategy will occur only after the demonstration of tangible benefits.

Integrated Crop Management Model

Implementation Plan

The strategy is based upon the concurrent use of a wide variety of crops in one block of land. The small-holder will be able to annually harvest food, pasture and/or fuelwood concomitant to building and maintaining soil productivity. The management schedule will be built around the maintenance of a continual vegetative blanket and relay harvesting of a diversity of species.

Small-holders grow living hedges from a number of shrubs, and a living hedge from local species is the most appropriate means of protection for the integrated crop management strategy. However, the pilot blocks will need protection as rapidly as possible in order to establish the model. Thus, it is deemed necessary to construct a metal fence around each pilot. The living hedge species will be planted within the perimeter. Once the living hedge is established (three years), the metal fence will be removed and used in future pilots.

Village participation will continue in the planting of crops and the establishment of the living hedge. However, project personnel would increase their responsibilities to building the metal fence, to weeding, and to building fire breaks. The integrity of the self-help concept will be maintained by the planting operation, and the probability of a successful pilot block will be enhanced by the extra protection given to the crops before the harvest. The paid labor for fencing, weeding and firelanes should come from the nursery crews and not from the participating villages. The current Fuelwood Project has done a remarkebly effective job of avoiding the association of village planting with salary.

The personnel in an integrated crop management project may deem it counterproductive to work with all villages currently participating in the Village Fuelwood Project. It is vital to have viable pilot blocks that provide the best possible demonstration. Some villages may not be enthusiastic. Continuing to work in those villages may place the success of the other pilots in jeopardy.

An effective extension effort is necessary for maximum impact. An extension program should be designed to provide the small-holder with the clearest picture of the intent of the project. It was found in the CARE-Chad

Acacia albida Project that farmers were the most effective spokesmen for the project. Farmers were filmed while participating in a project activity or next to a demonstration block. Their articulation of the benefits of the project objectives was often more effective than those of the project personnel. The filming was done with a Super-8 movie camera and the films were shown in rural villages with projectors powered by portable generators.

A tentative schedule for an integrated crop management block would be as follows:

Year 1. Construction of metal fence.
Planting of live-hedge.
Planting of all crops.
Weeding around perennials.
Make fire breaks.

Year 2. Replant for all crops.
Weeding.
Make fire breaks.
Harvest grasses as forage.

Year 3. Replant, weed, and fire breaks.
Remove metal fence to another site.
Prune living hedge.
Permit controled grazing within perimeter.

Year 4. Make fire breaks.
Permit controled grazing within perimeter.
Harvest foliage from browse species.

~~The findings of this investigation strongly suggest that the~~ emphasis of

Year 5. Selectively harvest fuelwood.

Harvest foliage from browse species.

Permit controled grazing within perimeter.

Make fire breaks.

Intercrop corn or fonio in areas of fuelwood harvest and continue to intercrop for next two years or until the recoppicing fuelwood shades it out.

The Crops

The crops chosen for this model will be selected upon the basis of their products and/or upon their soil-building ability. The trees, shrubs and some of the legumes will be raised in project nurseries. The composition of crops will include the following:

1. Trees

a. Gmelina will continue to be planted as a fuelwood crop as in the Community Firewood Project. They will be planted in double rows, each row two meters from the other. There will be a ten meter alley between the double rows. Trees will be five meters apart within rows. The adjacent rows will be staggered so that no tree is less than about three meters from another fuelwood tree. The trees will be harvested every five to seven years. Other fuelwood trees will be tried for their effects on the soil as well as for their fuelwood production.

b. Parkia biglobosa is a tree currently protected by the small-holder as a source of fruit that is used in sauces (soumbala). It is often seen on "tapades" and in fonio fields. It has a spreading, sparsely foliated canopy and crops appear to experience few negative effects from its light shade. It will be planted every ten meters within the fuelwood tree rows. A deep-rooted legume, it can be expected to effectively provide the topsoil with nutrients and organic matter.

2. Shrubs

a. Nonko (Ficus bougouanouensis), Maronai (Albizia gumifera), Bani (Terracarpa sp) are favored browse species. They are woody legumes native to the Pita region which will provide nutritious forage as well to effectively rebuild the soil. Although both will develop into trees, they both would best serve as shrubs. Once established (two to three years), their foliage will be harvested for year-around fodder. Controled grazing can be done or the foliage could be taken to an animal parc.

b. Leaucaena is an exotic legume that will grow more than a meter a year and produce copious amounts of foddr in the Pita region if the conditions are right. Acid tolerant Rhizobium is being used during 1984-85 in the Fuelwood project. Molybdenum containing fertilizer may overcome some of the effects of soil acidity but under the improved conditions of a managed block, it should do well.

3. Herbaceous Legumes

a. Crolateria is an introduction that has succeeded in reproducing naturally. It has promise as a forage as well as soil builder.

b. Cajanus cajan has done well in FAO trials in Pita. It will provide wood as well as browse. It is cited by Lisowski as being found wild in Guinea.

4. Grasses

a. Penisetum is an excellent forage that tolerates heavy browsing. It should be established as a pioneer grass throughout the block except where it would choke out the perennials and the legumes.

b. Andropogon gayanus is a deep rooted perennial that provides forage and construction materials. It should be established in rows five to ten meters apart and be harvested every year.

c. Bamboo (Bambusa vulgaris) is a favorite forage for cattle. It is often seen in the tapade fence lines and is pruned as browse.

5. Experimental Crops

There are a number of crops that could provide the necessary products and/or help rebuild the soil. These crops should be tried in a specific experimental block and should not be introduced into village plantations until their adaptability has been proven. The best possible conditions should be provided during the introductions.

a. Woody Legumes.

i. Acacia albida is well-known in the Sahel as a permanent intercrop where its reverse deciduous cycle permits crop production under its crown. The benefits from a canopy of A. albida are well chronicled by Sahelian farmers and early colonial officers. More recently the increaes in yields and the affects on the soil properties have been quantified by scientists (Felker, 1978). Although well known for its adaptability to the dry Sahel, its presence has been reported in areas of greater rainfall and higher altitudes than the Pita

region (Giffard, 1974; Wickens, 1969). The soils of Pita region are more acidic than those of the Sahel, but A. albida is also found in the Casamance area of Senegal where annual rainfall may be greater than the Pita area and acidity may be near to that found in Pita region soils. Seeds from the Casamance should be tried. If acidity is a problem, we could expect to find aluminum or manganese toxicity or deficiencies in Ca, P, Mg, or Mo. The latter would probably most affect the development of the Rhizobium. Several approaches could be tried:

i. The addition of Mo and Co fertilizers (about ten ppm) and organic matter to potting mix, the use of large pots, and the enrichment of the planting hole with organic matter and ash would buffer the effects of acidity. #19

ii. The use of acid-tolerant Rhizobium should be explored. (Contact Professor M. Gueye, Rhizobium, MIRCEN, Centre National de Recherches Agronomiques, d'Institut Senegalais de Recherche Agricoles, B. P. 51, Bambey, Senegal.)

It is probable that the A. albida could be successfully introduced into improved fallows with little soil amendment, and, once established, the tree should modify the soil conditions to favor its own development.

ii The genus Prosopis includes two species that have been successfully introduced into the drier areas of West Africa. They should grow rapidly under the rainfall of the Pita region but they would have to undergo the same introduction trials as the A. albida.

iii. Gliricidia sepium is a fast growing tropical tree that is widely used as a source of fodder and firewood in Latin America. It reportedly recoppices vigorously after being burnt or cut. Nodulation has been observed in trials in Mexico. It is easy to establish and reportedly does better on acidic soils than Leuceana. It is also tolerant of soils low in P (Nitrogen Fixing Tree Association, 1984).

b. Grasses. Several forage grasses were cited by Sanchez (1976) as being acid tolerant and by Lisowski (1979) as native or having adapted to Guinea. Several are cited by DuPont (1976) as being prefered forages. The list includes Panicum maximum, Hyparranea rufa, Melinis multiflora, Paspalm spp and Bracheria spp. Paspalm has been cited by Russell (1973) as harboring Azotobacter paspali, a nitrogen fixing bacteria.

Grasses are important beyond their forage value. There are nutrients such as phosphorous which are not heavily leached and are found in the topsoil or just below the top horizon. Phosphorous is often complexed by aluminum or iron and grasses may play an important role in breaking that complex and returning P to the nutrient cycle.

c. Herbaceous Legumes. Sanchez also cites several acid-tolerant legumes used as tropical forage. They include Stylosanthes spp., Desmodium spp., Centrosema spp, Calopogonium spp, and Pueraria phaseoloides. All but P. phaseoloides were cited by Lisowski as occurring in Guinea. FAO in Pita is currently having some success with Peuraria.

b. Parkia biglobosa is a tree currently protected by the small-holder as a field tree, and part of topsoil.

Potting Soil Preparations

Composting

Composting is a means to concentrate the nutrients from plant litter and to increase soil humus. In a compost system, the organic matter that makes up dead plant tissue is decomposed by microbial digestion at a relatively slow rate. Consequently, carbon is generally lost as CO_2 faster than plant nutrients, and the nutrients increase relative to the carbon. Moreover, the slow breakdown process produces a relatively high quantiy of humus, a recalcitrant compound that increases CEC and acts as a reservoir plant nutrients which are slowly released into the soil solution. Humus is extremely important to the tilth of the highly leached soils of the Pita region.

The best compost is produced under anaerobic conditions. If too much oxygen is present during the process, decomposition occurs relatively rapidly and the humus content will be correspondingly lower. Moreover, nitrogen and sulfur compounds will be more likely to escape as gasses.

The choice of plant material is important and varies with the intended use. Legumes are particularily rich in nitrogen. (They have a C:N ratio of less than 20 whereas grasses are generally in the 80:1 range.) Legumes grown in the nursery may be turned in to make a rich component of potting soil.

Lignin-rich plant material such as perennial grass culms (Andropogon spp) may enrichen the humus content of potting soils. Lignin breaks down more slowly than leafy plant material under composting. However, the composting conditions would have to be anaerobic due to the danger of attracting termites to the compost and infecting the potting mix.

Fresh grass is important to the process because it provides an energy source. In this case the high C:N ratio is beneficial because microbes use the carbon chains as energy.

Ashes

Wood ashes are a useful fertilizer and liming material. They have been effectively used to increase nutrient levels and pH on acidic soils. While nitrogen and sulfur are generally lost during burning, the basic cations (Mg, Ca, and K) are released in soluble forms. Moreover, the soluble forms are chemically suitable as a liming substance. (Berg, 1978).

Pulverized ashes could be added to the compost. It should be layered and it should not be too heavily concentrated as it may interfere with some types of microbial action, especially that which breaks down lignin. It may also be added to the potting soil mix separately. Ashes should be kept dry until they are to be added to the soil or compost.

The selective addition of ashes to field soil would help the establishment of legumes. When the legumes are transplanted from the nursery, a hole larger than the pot should be evacuated and refilled with a soil rich in compost and ash. That soil may be prepared in the village compost pits prior to transplanting in the pilot plot. The benefits of composting and using ashes may encourage a better use of animal manure and cooking fire ashes. (This is actually practiced on tapades but preparation of soil prior to its use is still little appreciated.)

Erosion Control

Erosion is a serious problem in the Pita region as the vegetative cover is decreased. It is especially serious on the hillsides which are being cleared at an increasing rate. To control erosion, the velocity of rainwater flowing over the soil must be decreased.

Greater infiltration is one important factor. Soils covered by plants receive rainfall more gradually than bare soil and a greater opportunity is provided for infiltration. Soils with better aggregation, as found in soils high in organic matter, are more permeable to rainwater. On the other hand, the surface of a soil under recently burned vegetation is going to have many pores plugged by gummy organic products from the fire. #21

Thus, a perennial cover as proposed in the integrated crop management strategy should be established on farmsoils. And, fires should be restricted by the establishment of fire breaks. (Many tapades have trenches around the perimeter which serve to protect the fields from fires as well as from animals.)

Hillsides pose an additional problem due to the steepness factor. First, rows of perennials should be established perpendicular to the slope. These plants should have commercial value. Cashew nut trees are used in several tropical countries. Leuceana is used on hillsides as a browse in others. Secondly, trenchs should be dug in conjunction with the plants. Ideally, the plants should be established on the high side of a trench. This would funnel water to the root systems and enhance growth. The trenches would have to be wide enough to collect water and eroding soil without being overwhelmed in the process.

APPENDIX

Plants for Consideration for Inclusion into Integrated Crop Plantation

Forage Plants

Dr. Bah's thesis (1976) lists forage plants common to the Dalaba district to the south of the Pita region. It is assumed that the plants found in the Dalaba district occur in the Pita region or could adapt to the region. He catalogues his plants as grasses, legumes or woody perennials.

Grasses (Graminees): Predominantly annuals with shallow root systems. The nutritive value depends upon the plant stage.

Anadelphia longifolia (Tinte): Found on Hydroolmorphic (Hollande) soils; not heavily browsed.

Andropogon gayanus (Ndyobon): Perennial with deep root system. Found on humid and fertile soils.

Chasmopodium codatum (Kalin): Vigorous perennial found on water courses and along ditches. Drought resistant. Good pasture in young stages.

Chloris prieuri (Kudhal Sari): Annual found on diverse sites. Good forage for all animals before flowering.

Coix lacrimajobe (Kudhi Kali): Perennial and green year around on lowlands, marshy areas and along water courses. Young leaves are sought by cattle.

Cynodon dactilon (Duguru Leydi): Perennial, rhizomous, and adaptable to a wide variety of soil conditions. Resprouts easily and green all year around. Favored by cattle.

Diectomis fastigiata: Found on skeletal (Bowe) soils. Good pasture in early stages and good hay.

Eleusine indica (Sigiri): Drought resitant and found on lowlands. Good pasture and resists trampling.

Hyparhenia rufa: A perennial found in wooded savannas. Its leaves are sought as forage.

Imperata cylindrica (Sooyho): This is the rough-edged pioneer known as "chien dent" (dog's tooth). It is a toublesome weed that pioneers young fallows. While the young leaves are reportedly browsed, it is a plant that chokes out more desirable species. It is a rhizome and associated with poor soils.

Loudetia coarctata (Burirdhi): Perennial found on hillsides and skeletal (Bowe) soils. Good pasture in young stages.

Oxythenatera abyssinica (Kewe): A lignious perennial found in living hedges. Provides year-around forage.

Paspalum scrobiculatum (Kenkesama): Found on moist, low land soils. Sprouts sought by animals. (Reported by South American researchers to harbor nitrogen-fixing bacteria.)

Pennisetum spp: Preferred pasture species. Some species very hardy and withstand heavy grazing if well-established.

P. pediselatum (Wulunde): Annual that is a preferred browse for cattle.

P. purpureum (Puki): Perennial found on deep soils and lowlands.

P. subangustum (Puki): Annual that is preferred cattle browse.

Panicum maximum: Robust, resistant to drought and favored by cattle. Common to alluvial soil and high-grass savannas.

Rotboelia exalta (Kalin): Common on sandy-silty soils of low lands and plateaux. Successful under dryland conditions. Good pasture when young and resprouts after brush fire.

Sporobolus pyramidales (Fonnye Tyolli): Perennial found on sandy clay soils of dry plaines. Not greatly sought as a browse.

Legumes: Legumes generally have deeper root systems than grass and have the capacity to form symbiotic relationships with Rhizobium, a nitrogen-fixing bacteria. (Molybdenum is one of the major requirements for the nitrogen-fixing enzyme, but available Mo is generally deficient in acidic soils. The introduction of legumes into degraded soils may be enhanced by the addition of small amounts of molybdate to nursery soil. Once the soil has been buffered by additions of organic matter, the need for this amendment should be reduced.--See Conclusions and Recommendations.)

Albizzia gumifera (Maronai): Shrub found on hillside. (According to surveys of farmers and officials, Maronai is one of two species most sought out by herders to prune for their herders. The species may have been incorrectly reported inthe thesis as it was stated that it was not a favored browse.)

Cassia sieberiana (Sindya): A shrub found on diverse soil types. Leaves not heavily browsed. Seeds are toxic to cattle..

Colopogonium micunoides: Found on light soils. Sprouts, leaves and fruit are browsed by cattle.

Dialum guineense (Meko): Small tree found on savannas and along water courses. The fruit is consumed by goats when other browse is short.

Dicrostatis glomerata (Bulle Bete): Tree found on shrub savanna. Leaves browsed by goats.

Ficus bougouanouensis (Nonko): Tree found on savanna and in gallery forests. (Nonko is one of two species most sought out by herders.)

F. vogelei (Yhibbe): Commonly occurring shrub found on savanna and along water courses. Fruit and leaves browsed by goats.

Lewgnuko spp.: Found on skeletal soils. Whole plant consumed by goats.

Mucuna pruriens (Baagi): Creeping bush found on woody savannas along water courses; very common in mountains. Leaves are browsed by cattle but hair on fruit produces itching.

Parkia biglobosa (Nete): Large tree with spreading canopy. Common and found on a variety of soils. Leaves are browsed by cattle. (It is one tree protected by small-holders because of fruit which is made into "soumbala", an ingredient for sauces used across the Sahel. Its spreading, thinly foliated canopy accomodates cultivation of fonio. It is also frequently seen in tapades.)

Pterocarpus erinaceus (Bani Bhale): A shrub whose habitat ranges from scrub savanna to full forest. Leaves are browsed by cattle.

Tamarindus indica (Dyabbhe): Tree bearing the "tamarind" fruit. Fruit and leaves acidic and not highly palatable.

Other species that provide browse during the dry season.

Alchornea cordifolio (Garkasaki): An Euphorbiaceae found on the savanna and in forest understories. It is a shrub that is resistant to fire, and its leaves are browsed by goats.

Adonsonia digitata (Bhohe): Large tree of the Bombaceae family with leaves and fruit browsed by cattle, sheep,and goats.

Amona senegalensis (Dukumme): A shrub of the Amonaceae family. Not heavily browsed.

Bidens pilosa (Kebbe): Herbaceous plant found on Hydromorphic and skeletal soils. Leaves browsed by cattle.

Chlorophora regia (Tyimme): Tree of woody and herbaceous savanna. Leaves are browsed by cattle during fodder shortages.

Ceiba pantendra (Bantan): Tree of the Bombaceae family. Well known as the "fromagier". Flowers and leaves browsed.

Gardenia triacantha (Boss): A shrub of the Rubiaceae family found on bush savannas. Flowers, leaves, and fruit are browsed by cattle, sheep and goats.

Himenocardia acida (Pellitoro): A shrub of the Euphorbiaceae family found on bush savannas. Leaves browsed by goats.

Landolphoia heudelotii (Pore Kodudu): A savanna and understory shrub whose dry leaves are browsed by goats.

L. hirsuta (Pore Lamman): Understory shrub whose leaves are a dry season fodder.

Lophira lanceolata (Malanga): Shrub of the Ochnaceae found on skeletal (Bowe) soils of the savanna region. Leaves browsed by cattle and goats.

Markania tomantose (Kafa wandu): Shrub found in understories and on bushy fallows. Leaves browsed by cattle during dry season.

Mitragina stipulosa (Poopo): Tree of the Rubiaceae family. The young leaves are browsed.

Parinari excelsa (Kura): Tree of the rose family found on a variety of soils. The fruit and leaves are browsed.

P. benna (Sigor): Tree of the rose family; similiar to P. excelsa.

Triumfetta cordifolia (Mamanata): Shrub found in gallery forests or on otherwise fertile soils. Indicates good soil. Leaves and flowers browsed by cattle.

Toxic plants: In periods of fodder shortage, the following plants are sometimes browsed. Consumption by animals can cause sickness or death. These plants should not be intercropped with pasture crops. If they are planted for fuelwood, a hedge should separate them from browsing animals.

Ageratum conyzoides (Kikala Purel): Herbaceous plant with flowers that are toxic to cattle.

Anacardium occidentale: The cashew tree found in compounds and gardens. The seeds (leaves?) are toxic.

Canthium venesum (Sendhengel): Whole plant is toxic.

Decapithelum toxicaruim (Meene): Shrub found along watercourses and in understories. Leaves are highly toxic.

Erythropheum guineense (Teli): Tree furnishing high quality fuel. Leaves and bark are toxic.

Ricines coomunis (Dyakula): Shrub with seeds that are highly toxic to cattle.

Medicinal plants used by farmers for animal husbandry. See Dr. Bah's thesis for more detail on use.

Anisophylla lairina

Bauhinia toningii-schum (Barke)

Cassia sieberiana (Sindya)

Erythrina senegalensis

Holarrhena african (Dunki Manya)

Khaya senegalensis

Markania tomentose

Parinari benna (Sigon)

Pterocarpus santa-llinoides (Dyegu)

Another Village Reforestation Projects in West Africa

CARE-Chad/USAID/GOC Acacia albida Project, Republic of Chad, 1976-1980

This village level, self-help reforestation project was undertaken by CARE-Chad and the Chadian Forestry Service to increase *Acacia albida* trees in grain fields. The project, funded by the two participating agencies with an additional large contribution from USAID, worked in some 50 Chadian villages to establish *A. albida* trees in farmers' fields, establish village woodlots, plant shade trees in village markets and to establish living hedges. The *A. albida* tree requires at least ten years to have an impact on soil agricultural productivity and the establishment of the tree was considered as a "public service" that would serve the common good and not necessarily that of the farmer who planted it. It was not expected to have a multiplier effect; its rationale was based upon concern for the longterm productivity of the soil.

The other components of the project were designed to promote a multiplier effect, however. The project was not fully operational during the five years due to the civil war, but farmers began to request living hedges for their gardens and fields within four years after the project begin. The demand was generated largely from living hedge models established around schools, along market roads, next to hospitals -- anywhere it would be visible. Once established and pruned, the living hedge (*Parkinsonia aculeata* and *Prosopis juliflora*) proved to be effective at keeping out animals and easier to maintain than dead thorn fences. From the small-holder's point of view, planting seedlings and caring for the shrubs was less effort than to annually cut thorn branches and transport them to the site. From the Forestry Service's point of

view, fewer young trees and shrubs would be harvested annually. From the project managers' points of view, tangible models proved to be effective means of achieving a multiplier-effect.

The pilot fences were established under conditions similiar to a farmer who would want to keep animals from his millet fields or his garden. And, they were established in prominent places to maximize exposure. Finally, every effort was made to produce a high survival rate. In trying to demonstrate the effectiveness of a technique, it is necessary to leave the best impression; not to depend upon the imagination of the target group.

Traditional Farming Strategies in Other West African Countries

Traditional husbandries and other development schemes were studied for strategies that may be applicable for the Pita region.

The Serer of Senegal (Pellissier, 1966)

The Serer are a farming group of Senegal who use a mixed economy and short rotations to achieve sustained yields of food, fodder and commodity crops from limited land resources. Their farms are partitioned into three parts which are rotated among millet production (home consumption), groundnut production (commodity crop), and grazing. Living hedges are established between fields to protect crops from the grazing animals.

The *Acacia albida* tree is used as an intercrop on the entire farm. This large legume is known throughout the Sahel as a permanent ground cover under which grain yields are doubled relative to the open soil (Felker, 1978). Moreover, the tree provides high quality fodder (leaves and pods) during the dry season when animal feed is generally low in quantity and value. The presence of the A. albida gives the terrain of the Serer a park-like aspect

which maintains productivity concurrent to providing a relatively good and reliable harvest for the Serer small-holder.

The Wolof of Senegambia (Gamble, 1957)

The Wolof farm and maintain cattle herds along the Atlantic coast of Senegal. The effects of population pressure can be seen in the contrasting farming systems found among the Wolof. In areas of low density, when the bush is cleared for millet production tree and shrub stumps of three to four feet are left. Consequently, when the land is fallowed the woody vegetation quickly reestablishes itself helping to restore soil fertility. But, on areas under heavy demographic pressure, vegetation near the older villages has been thoroughly cleared.

Fertility maintenance in high density areas is done by systematically covering the farmland with manure. Cattle are tethered every evening in a "parc". By moving the parc every few days, the entire field will eventually be covered. (Comment: it would be important to have a convenient source of high grade fodder such as the leaves and pods of the *A. albida* tree.)

A second method of maintaining fertility is to intercrop millet among the rhum palms which often border swamps and waterways. In the Wolof farming system under demographic pressure, either constant manuring or intercropping in palms appears to enable the small-holder to farm for more than a few years without soil exhaustion. (Comment: Gamble made no mention of use of the *A. albida* by the Wolof.)

The Wolof are major producers of groundnuts for export. Apparently this crop has been developed at the expense of the soil's productive capacity. Fires are used more frequently for clearing and overcultivation is increasing. Consequently, progressive soil deterioration and woodland degeneration is under way.

The Bambara (Pacques, 1954)

Household gardens are intensively worked without fallow. The fertility is maintained largely from addition of household wastes (much like the tapades of the Pita region small-holder). The beds are multi-cropped providing multiple story canopies and root profile. The primary purpose of these gardens are to ensure food supplies during the time of want between grain harvests.

The value of the bush fallows is enhanced by the practice of leaving 0.70 to 1.00 meter of stump from trees and shrubs when the fields are cleared. It is felt that a rapid reestablishment of the bush fallow shortens the period necessary to rebuild the soil.

Multiple-cropping is often practiced by small-holders to improve grain production. One may find a number of the following crops associated in one field: millet, maize, beans, cotton, peas, peanuts, sweet potatoes, manioc, and gumbo; each plant exploiting a different part of the soil profile.

The *Acacia albida* plays a major role in the mythology of the Bambara. It is known by small-holders to improve grain production and to provide a high quality dry season fodder.

Notes from a Meeting with General Sow, Director of Rural Development of the Pita Region:

Dr. Sow is an experienced agronomist as well as a chief administrator. He provided me with systematic exposes on the genesis of soil degradation, agricultural systems, plant-soil associations, and indicator plants.

Genesis of soil degradation: Sub-mountain or savanna vegetative cover was a climax forest (forets submontagnard). Man's intervention caused a degradation of forests and soils. The degradation process was as follows:

1. Clearing of forests for crops and pasture opened the soil to erosion and leaching of soil.
2. Subsequent brush fires and increased grazing pressure impeded reestablishment of young forest species. Pioneer grasses came to predominate.
3. The consequences of loss of tree cover on the soils of the Fouta-Djalon under a six-month rainy season that averages 1400 mm of rainfall are:
   a. erosion of topsoil;
   b. leaching of bases leading to acidification; and,
   c. reduced ability of shallow-rooted grasses to pump bases to counter acidification.
4. Thus, we have had a gradual change from a submountain forest to a grassland savanna. This process has become accelerated as pressure on the land increases and less opportunity is provided for reconstitution of forest species:
   a. shorter fallows create a spiral of plant and soil degeneration and the effect tends towards permanency if the spiral is not checked;

b. brush fires set by herders kill young seedlings ;

c. overgrazing disproportionately affects young shoots as they are preferred browse;

d. firewood gathering for home-cooking, bread-making, and brickmaking disproportionately degrades the forests and soils around population centers. (Comment: pressure for wood also creates a ready market for fuelwood lots.)

General Sow said that the pedogenesis (soil development) of the Pita region could be seen in soil profiles. One would find layers of charcoal remaining from forest and brush fires that periodically cleared the land of trees. He felt that forest canopies could be reconstituted. But pressure for cultivation and grazing would not permit it unless a tree that accomodated cultivation could be established. The Acacia albida would fit the role and efforts should be made to establish it.

Indicator Plants

General Sow provided us with a list of indicator plants. He listed them by topographical category:

Bas-Fonds: Lowlands characterized by hydromorphic soils. They are the most fertile and often have an accumulation of humus.

1. Raphia gracilis (Palmeae)- This palm is associated with rich soils suitable for rice, pineapple and banannas. It is very deeply rooted and difficult to remove manually, thus small-holders intercrop. (Comment: the Bambara find intercropping with the Raphia is beneficial for crop production.)

2. Sporobilus pyramidales (Gramineae)- This grass indicates good soil but it may be weedy in that it is difficult to remove once established.

The following plants also indicate that the soil is well rested and capable of supporting a crop:

3. Cyperus rotondus (Gramineae)
4. Azeratum conyzoides (Composeas)
5. Penisetum substratum (Gramineae; also noted as fine forrage)
6. P. pedicellatium
7. P. purpureum
8. Alahornea cordifolia (woody shrub)

Plateau (Plaine de Timbi - Timbi Plaines)

1. Borreria verticilata (Composeae)- Indicator of poor soil.
2. Hymenocardia acida - A shrub often associated with poor, rocky soil.

Mountain (Montagnard)

1. Andropogon gayanus: Indicates soils rich enough for rice or peanuts. (Comment: this plant generally found on humid soil; thus, the site would probably be on a waterway.)

Alluvial Soils found along Waterways

1. Imperata cylindrice: A weedy grass that is generally found on deep clayey soils.
2. Penisetum subargutean: A good forage grass found on good soil that may support rice, manioc or sweet potato.
3. Cynodum doctylon: A grass that indicates moist soil; often found in a depression.

Living Hedge Species

The Pita region is rich in living hedge species. Many small-holders take advantage of this wealth to protect farmland and tapades.

1. Lantana camara - A thorny bush that spreads out. Especially effective when top-pruned.

2. Agave americana - Better known as sisal, this short, spiny plant is effective against domestic animals, and, if well established it may serve equally well against monkies.

3. Jatophia citiata - This was a reported species; its effectiveness was not verified first hand.

4. Ficus spp.- Several species of the Fig family are used by farmers as living hedges. They are established from cuttings which is a major advantage, and some are a good source of dry season browse.

(Comment on living hedge extension- the transport of living hedge cuttings to small-holders would be a good investment. The cuttings that are transported to small villages will soon provide cuttings for further extension.)

Soil Types

General Sow outlined the characteristics of the important soils in the Pita region.

Ferralitic Soils (Sols Ferralitique): The predominate soil type and the most widespread. Found on mountainsides and the plaines. The primary characteristics are as follows:

1. pH 4-6;
2. deep, generally 30 cm over rock;
3. low in exchangeable bases; and,
4. they have a reputation for being susceptible to laterization.

Skeletal Soils (Sols Squellitique): Characterized by thin soil and frequent outcroppings. Generally eroded and degraded. Known also as "Bowe" soils.

Hydromorphic Soils: Best soils for many crops but limited by extensive waterlogging. Soil pH often 4 -6, but may be high in humus.

Alluvial Soils: Usually found along waterways where eroding soil is deposited. Related to hydromorphic soils. Often acidic.

The FAO Forage Experiments in Pita

The FAO project in Pita directed by Mr. Stephanesko has experimented with a number of tropical legumes and grasses as forage. The results should be closely examined by those working in integrated cropping schemes. Mr. Mammadou Sallou Fall gave us a tour of the fields around Pita.

The Field Trials

Exotic Species

- *Panicum maximum*- grass planted in latter part of rainy season, and is suffering effects of drought. May do better if planted earlier.
- *Samania saman*- Australian legume, planted out from pots and showing fair growth despite weed competion.
- *Stylosanthes humilius*- legume, resistant to trampling and overgrazing; broadcast with fair take.

-S. amatat - broadcast, observed active nodules; deep tap and reportedly drought resistant and capable of reseeding itself. Good potential as late season browse and grownd cover.

Canaualia ensiformis- shrub planted from seed; leaves and fruit are browsed but caution needed as they are somewhat toxic.

-Vignia syneocus- fruit and leaves are browsed; poor take on this site but may do better on improved site.

-Centroseam pubescens- planted in alternate rows with P. maximum.

-Cajanus cajan- seeded in pockets in July; doing poorly in tall grass but may do better without heavy competition.

-Subclover species from Australia - sparse, produces small leaves close to ground.

Native Species

-Cassia sibieriana-dry season fodder; could be used to extend grazing season.

-Dichrostachy glomerata-same as above.

-Penisetum hordoides-perennial grass with long and succulent blades; this may be a quality plantation species under controlled grazing.

-Albizzia sp.- large tree known for its forage quality. Sought out by herders during dry season but not protected from fires.

Hymenocardia acida-dry season fodder for calves and kids.

Nursery Trials

This is a listing of species found in the Pita FAO nursery.

Melinis minutiflora

Glycine spp

Stylosanthus guianesnsis

Vignia cynescens

Crotalaria sp

Desmodium

The following are the notes on the status of fuelwood species of the Pita region. These notes were prepared by M. Foinke, the Director Adjoint of the Forestry Service of Pita. Included are mention of some field experiments undertaken.

Les espèces en disparition :

N°	Sous préfecture	Espèce	Peuplement	Disparition
1 -	Sangarédi	Linguè	faible	En disparition
		Simè	+ ou moins	en voie de disparition
		Popo	dense	en forte densité
		Téli	faible	en densité faible
		Koura	plus ou moins	en voie de disparition
		Néré	dense	Forte densité -
2 -	Maci	Simè	plus ou —	En voie de disparition
		Popo	faible	En voie de disparition
		Teli	faible	En voie de disparition
		Linguè	très faible	En voie de disparition
		Koura	dense	forte densité
		Néré	dense	forte densité
3 -	Ninguelandé	Simé	plus ou moins dense	en voie
		Koura	dense	forte densité
		Néré	plus ou moins dense	en voie
		Linguè	faible	en voie
		Teli	dense	forte densité
		Popo	dense	forte densité
4 -	Timbi Touni	Simé	faible	en voie de disparition
		Koura	plus ou moins faible	en voie de disparition
		Popo	plus ou moins	en voie de disparition
		Néré	plus ou moins	en voie de disparition
5 -	Dongol	Koura	plus ou moins	en voie de disparition
		Néré	plus ou moins	en voie de disparition
		Téli	faible	en voie de disparition
		Simé	faible	en voie de disparition

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N°	Sous-préfectures	Espèces	Peuplement	Disparition
6-	Pita	Muro Nai	faible	en voie de disparition
		Koura	dense	en voie de disparition
		Néré	faible	en voie de disparition
		Téli	dense	
7-	Bourouwal	Téli	faible	en voie de disparition
		Koura	faible	en voie de disparition
		Popo	faible	en voie de disparition
		Néré	très faible	Echantillon
8-	Sintally	Koura	très faible	Disparition
		Néré	Faible	en voie de disparition
		Téli	faible	en voie de disparition
9-	Timbi Madina	Koura	Faible	en voie de disparition
		Téli	Faible	en voie de disparition
		Néré	Faible	en voie de disparition
		Lingué	Faible	en voie de disparition
		Simé	Faible	en voie de disparition
		Gobi	faible	en voie de disparition
		Popo	faible	en voie de disparition
10-	Gongoré	Koura	dense	En voie de disparition
		Néré	dense	En voie de disparition
		Téli	dense	En voie de disparition
		Simé	dense	En voie de disparition
		Gobi	dense	En voie de disparition
11-	Bantiguel	Koura	Faible	En disparition
		Téli	faible	en disparition
		Lingué	faible	en disparition
		Simé	faible	en disparition
		Néré	faible	en disparition
		Popo	faible	en disparition
12-	Ley Miro	Lingué	plus ou moins dense	En voie de disparition
		Simé	plus ou moins dense	En voie de disparition
		Téli	Forte densité	—
		Popo	Forte densité	—
		Koura	Forte densité	—
		Néré	Forte densité	—
		Gobi	Forte densité	—

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I | Bois de chauffe :

a) Espèces en disparition

1) Parinarica exalsa (Koura).
Cette espèce est généralement exploitée par les détenteurs des fours à pain, à briques et les charbonniers.

2) Sterculia : A densité très faible est beaucoup utilisé par les artisans spécialisés dans la fabrication des mortiers, pilons et escabots -

3) Albizia : Destinée à la confection des manches de Houe, coupe-coupe, Hache et couteaux.

II Bois de pâturage :

a) Espèces locales : Nonko, maronai, Albizia.

Nonko :

Maronai :

Albizia :

b) Espèces exotiques :

Leucaena leucocephala
Pois d'Angol, Tajanus-tajan
Sesbania sesban
Acacia albida
} en voie de vulgarisation.

- Données sur les projets de reboisement.

I ~~Production~~ Protection :

- Lutte contre la déforestation
- Lutte contre les ~~incendies~~ incendies
- Préservation de la faune
- Lutte contre les facteurs de dégradation des sols (canalisation, interdiction formelle à la masse paysanne la culture sur les fortes pentes).

Production : Reboisement à l'aide d'espèces locales et exotiques de toutes zones dénudées, les têtes de sources et les places publics. (Koura, parinare exalsa 30 à 40 %, tâli Hythrophyllum Guineensis

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Site I

Pit 1 Bantignel Nursery – Colluvial soil at base of Hill. Nursery borders Stream. It was in a bush fallow (five years) prior to being cleared last year for nursery use. The fallow vegetation was the same as the hillside vegetation but thicker.

A: Silty Clay loam, yellowish-red soil (Smooth and sticky; no grittiness)

18

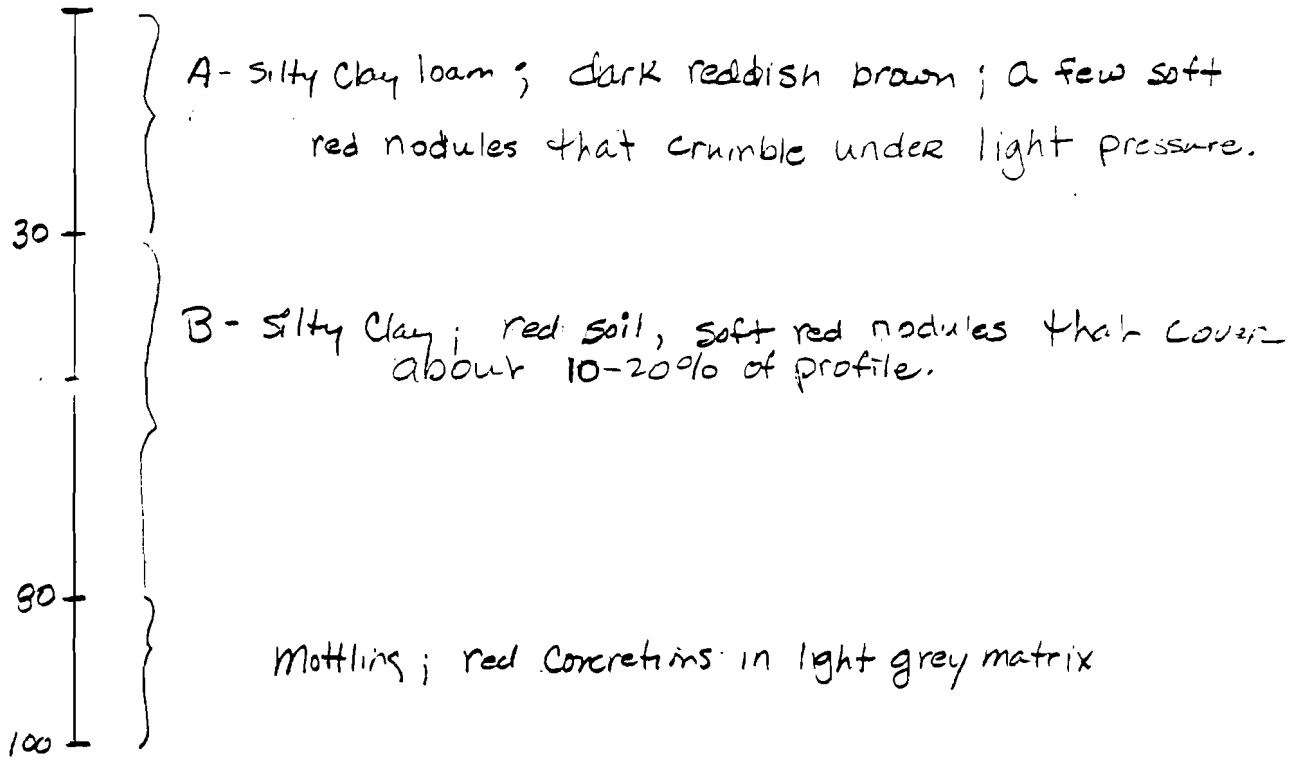
B: Silty-Clay; dark-reddish brown (Considerably darker than A horizon.)

94

150 red nodules (soft), no concretions

Site I

Pit 2 Bush fallow above Bartignel nursery



Pit 2 was 50 meters up the hill from the nursery. It is sparsely covered by shrubs and grass. The predominant shrubs were Cassia siberiana, Saumbala, and Radhpo. The hill is fairly steep and has rock out-croppings. There were signs of erosion.

Mottling of iron nodules were found closer to the surface in pit 2 than in Pit 1. The deeper profile of pit 1 probably had to do with the colluvial nature of the soil. Moreover, the vegetative cover at the base of the hill was probably more vigorous and extensive before being cleared.

Site II Mekansa village forest plantation

Pit 1 Lower site on hill

	A	silty-clay ; reddish brown
30		slight clay-loose
50	B	silty clay ; reddish brown, slightly darker than A
95		Bed of consolidated lateritic gravel ; yellowish-red matrix

Site II is on a moderatedly steep hill. Grass and small herbaceous plants are the predominate plants. Pit 1 is at near the bottom break of the hill and about 30 meters from a creek bank. Much of the profile is probably colluvial soil. I can not say whether the lateritic bed was formed before the deposit of the colluvial soil or if iron leached from the existing profile. Given the lack of mottling in the profile, much of the bed was probably in place before being overlain. And, iron may have leached out of the migrating colluvium and been deposited higher on the hill.

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Site II Melikansa Village Forest Plantation

Pit 2 Higher site on hill

	Silty Clay	light brown
20	Clay	light brown, a shade darker than top horizon
55	Bed of consolidated lateritic gravel, no mottling or nodules above this depth	

Pit 2 was 100 meters higher on the hill than Pit 1. Most noticeably, the profile was about 2/3's of the depth of pit 1 and the color of the profile was lighter. As in pit 1, no mottling appeared above the lateritic bed.

The predominant grass was Pennisetum spp (Pauki) indicating a soil of fair productivity by the judgement of Fita region farmers. There was also a small woody legume (Tchabulé) which had no sign of nodulation. A small mustard (dandané) was also common. Dandane reportedly indicates soils of fair productivity.

Site III Melikansa Cassia plantation

Pit 1: Within Cassia stand

=	O horizon; partly decomposed organic matter
	Silt loam Brown, streaked with dark organic matter
30	Clay lense at 30 cm
	Silty clay, Strong brown
	red nodules, iron-indurated at 50 cm (20%)
80	poorly consolidated bed of semi-indurated concretions

The Cassia simea stand is reportedly 24 years old. The stand is not uniformely dense but the trees are mature. The pit was dug under the canopy of several trees. The soil was covered with tree litter in various stages of decomposition. Roots occupied each level of the profile.

Site III Melinkansa Cassia plantation

Pit 2: Followed field adjoining Cassia simea plantation.

Silty clay brown, few soft red nodules

40 Bed of semi-indurated concretions; yellowish-brown

Pit 2 was on a five year old fallow that was dominated by grasses but included shrubs, Uvaria chamae being included.

Site II Cassia simea plantation on Pita-Bantigiel Road.

Pit 1: Located within a group of Cassia trees in a very sparsely populated, 20 yr old Cassia stand. There were few trees within this group and the apparent influence of this stand upon the soil was much less pronounced than the more heavily populated Cassia stand at Melikansa.

Ao

Silty Clay loam; yellowish-brown, horizon streaked with decayed matter

25

Silty clay; yellowish-brown
Soft red nodules are found at 25 cm and increase in quantity with depth, the nodules are non-indurated and easily rendered to powder by finger pressure

100

roots found to 100 cm

larger, more indurated nodules mottled in whitish-grey matrix

Site IV Cassia simea Plantation on Pita-Bantignel Road

Pit 2: Fallow grassland on moderate slope; pit 2 about 30 meters from pit 1. Both are about same location on the slope (about 200 meters from the top). The predominant vegetation in the fallow is Chien-dent ( ). There are a few small legumes in the fallow but no signs of nodules. There is no signs of influence of shrubs on the soil of pit 2. However, the shrub Doukoumal was found scattered in the fallow

0–28	Clay loam	reddish = brown
28–78	Silty clay	yellowish-red; heavier soil
78		roots of grass fallow found to 78 cm
78–130	Silty clay	yellowish-brown; non-indurated nodules begin at 78 cm
130		Mottling of red concretions and nodules in greyish-brown matrix

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Site V

Pit 2: Shrub-grass fallow. Both pits at base of moderately steep hill with 200-300 meter run. Both profiles have colluvial topsoil. The predominating vegetation near pit 2 is Boreria verticilata, Holarrhena africana, Parinari, Syzygium alticornium and several species of grass including Pennisetum sp. There were no woody plants in immediate pit vicinity. There was no chien dent

Clay loam reddish-brown

50

No roots found after 50 cm

Clay becomes more dominant after 50 cm

Clay light brown

130

Indurated layer; lateritic concretions in grey and brown matrix

Site V — Gmelina stand and shrub-grass fallow near Pita and adjacent to Pita-Labe road.

Pit 1: Twelve year old Gmelina stand. Gmelina mixed with a few pines and mature natural shrubs.

0–15	10Ym	Dark, reddish brown relatively high amount of organic matter
15–30		pockets of lateritic gravel (indurated ironstone);
30–73	10Ym	reddish brown
73–130	Silty clay,	light brown, semi-indurated nodules (< 10%)

130 — tree roots to 130 cm
lateritic gravel in brown matrix

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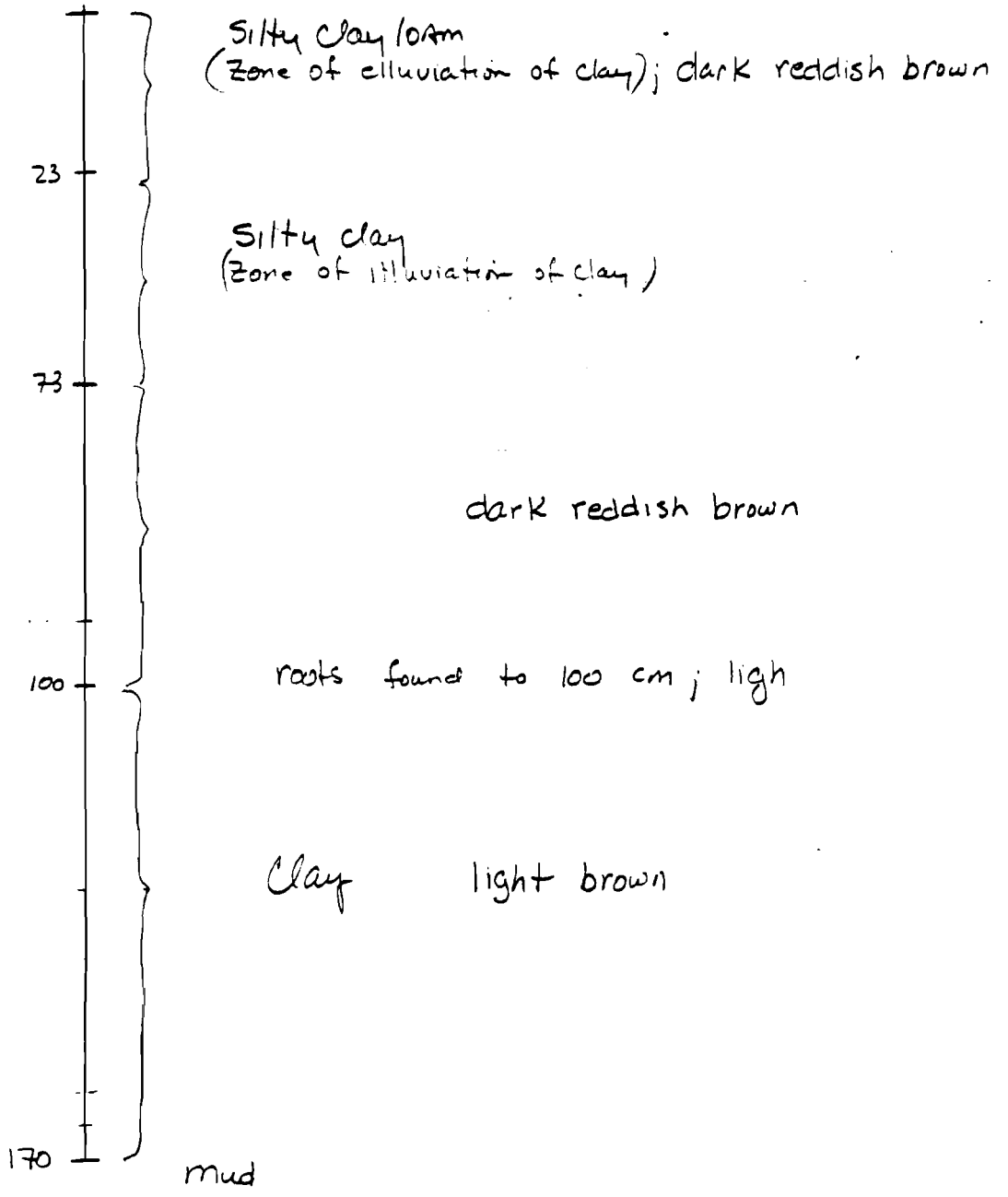
Site VI The Timbi - Medina nursery. The nursery is at the base of a hill with a slight slope. Part of the nursery is a drainage area and is swampy much of the year. Before the site was cleared as a nursery in 1983, it had been in fallow since 1974. The higher, less humid part of the nursery was in a predominant grass fallow and the more humid, lower part was predominantly shrub. Sample 1 was taken from a pit on the higher part of the nursery which had been cleared but not used for beds. Sample 2 was collected from the top 20 cms of the lower part which was cleared recently for beds. The soil of sample 2 was hydromorphic and was finally mottled with semi-indurated red nodules in black and bluish-grey matrix typical of seasonally inundated soils.

Pit 1: no nodules on face of cut



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Site VII Pit 2: Grassy fallow. Chien dent is the predominate vegetation. The topsoil was turned in 1993 by FAO in preparation for the pine plantation. No wood roots were found in the soil pit.

No A_0

Sandy clay loam

44

Clay loam, humid soil, soft iron nodules found at 78 cm; rhizomes of chien dent found throughout profile

78

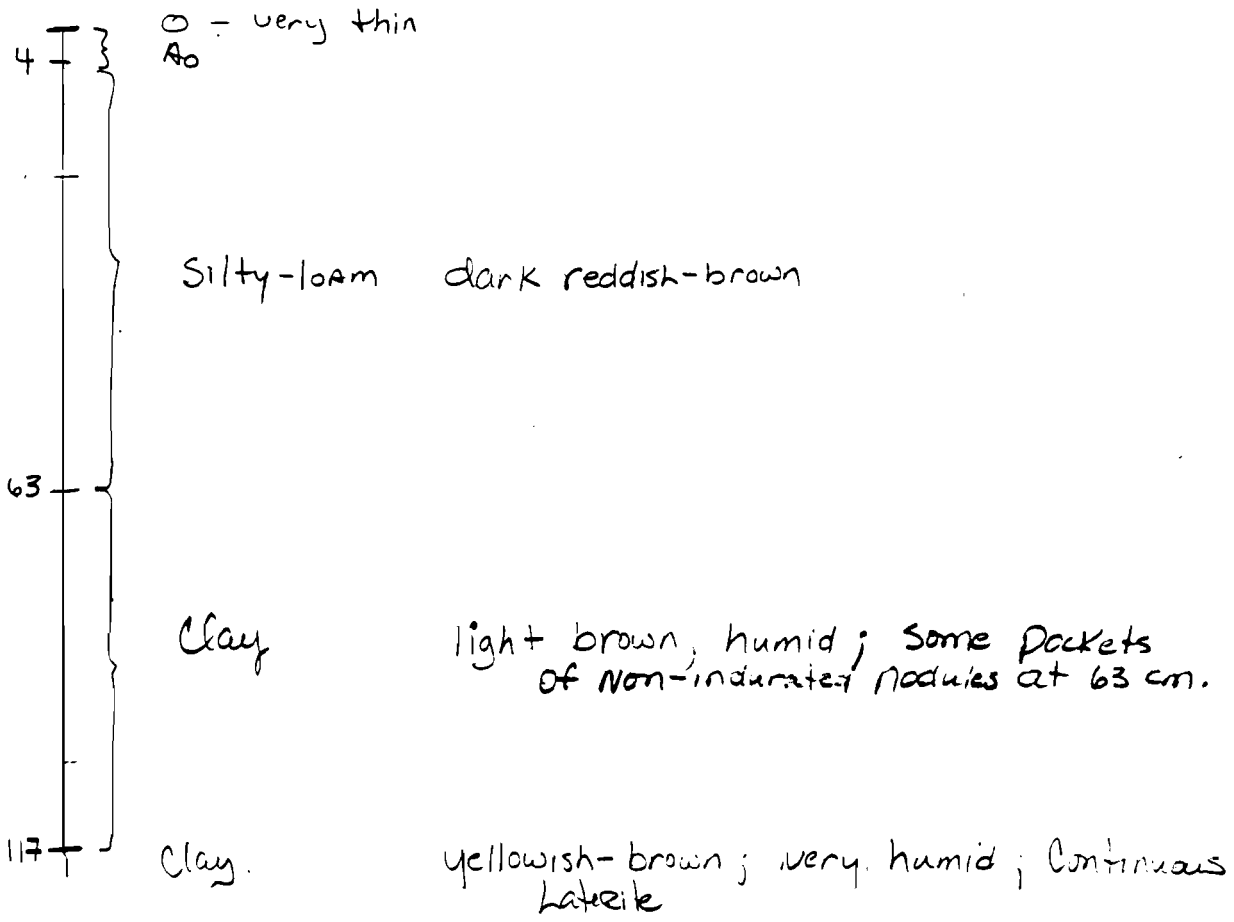
88

Continuous laterite; crumbly with thin black film found on lateritic crumbs. Black color suggests possibility of Mn in high concentrations.

Site VII

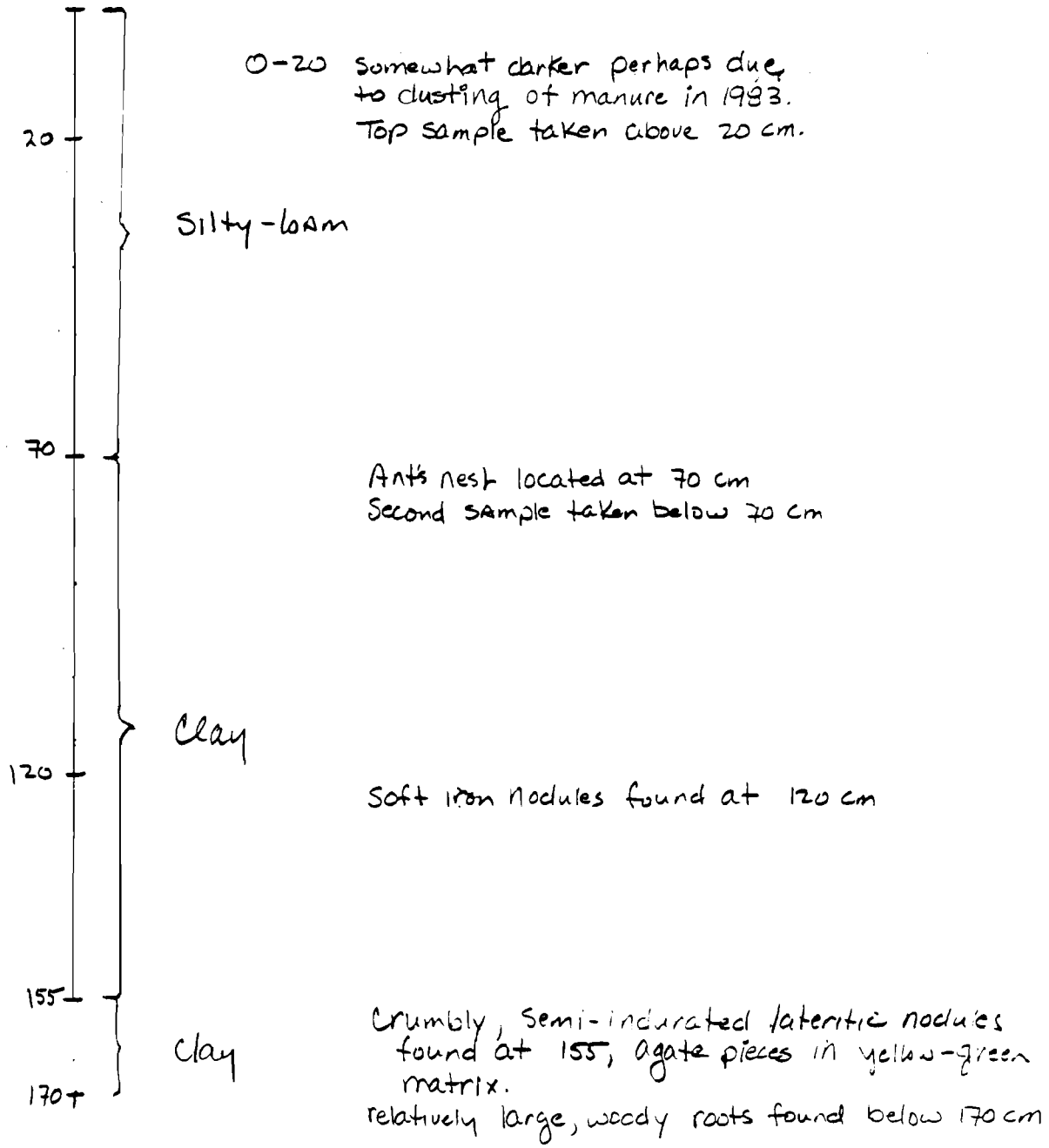
Pine Stand and Grassy Fallow Near Pita. The pine stand is reportedly 20 years old. The canopy is well-established with an understory of brush. *Pinus kassia* and *P. robusta* are both in the stand, although *P. kassia* is reportedly the only species to produce cones in Guinea. The fallow was ridged and planted into pines in 1983. However, grasses (primarily Chien dent) have the predominant influence on the soil. The sites were at about the same level on a moderately sloped hill.

Pit 1: Pine stand. There is an extensive woody-understory including the following: *Fagaria microfilia*, *Holarrhena africana*, *Syzygium alficornium*, *Uvaria chamae*, *Parinari excelsa*, *Boscia* spp, *Hymenocardia acida*, *Alchornea cordifolia*, and *Ficus* sp.



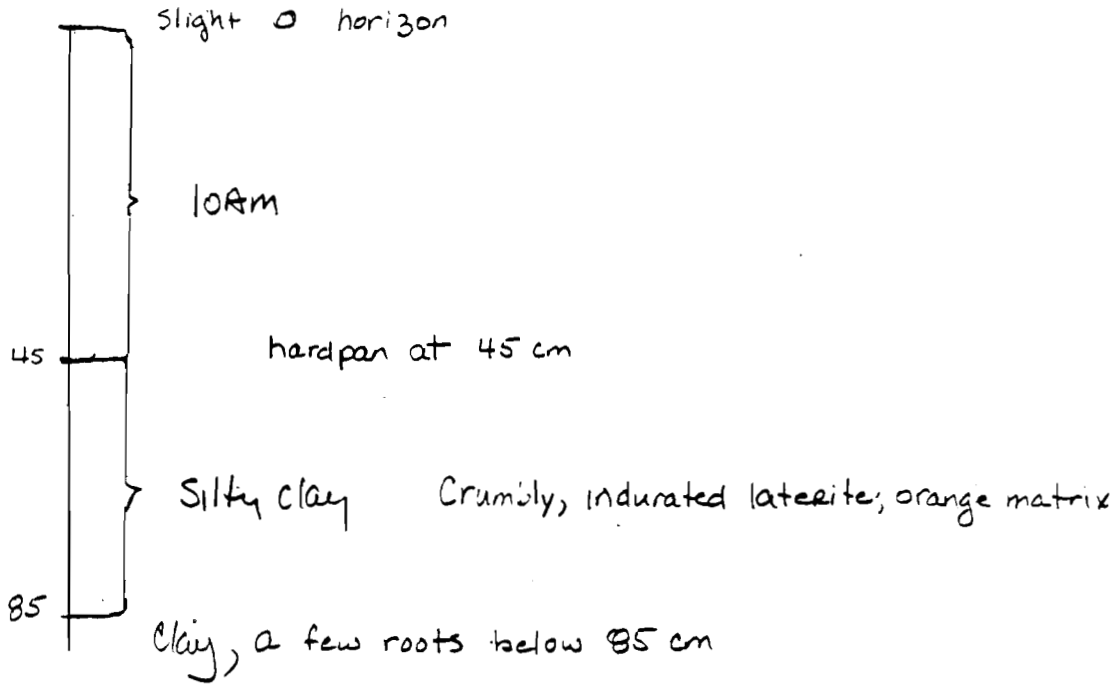
Site VIII Timbi-Touni nursery and Shrubby Fallow. The pits for the nursery and fallow sites were located on a moderately sloped hill. The nursery site was a little lower on the hill and appeared to have more colluvial soil.

Pit 1: Nursery. The nursery was established in 1983. The pit was located on a bed where bare-root stock of *Gmelina arborea* were grown. Grassy fallow predominated the nursery site before the land was cleared in 1983.



Site VIII

Pit 2: Shrubby fallow. The predominant shrub was Nyandugoki, a legume with a large population of active rhizobium. The duration of the fallow appeared to have more than five years.



Site IX M. Bary's fallow field, garden, and citrus orchard. The fallow field and garden are at the base of the same, steep hill. The field was previously in fonio and has been fallow for five years. The garden area was formed along a stream, it contains both colluvial (hillside) soil and alluvial (stream bed) soil. The citrus orchard is in an area near his house and is near the base of a moderatedly sloping hill.

Pit 1: Fallow fonio field. The pit was dug on a grassy site near the garden. While grasses predominated the pit site, shrubs predominate some areas. The predominant plants were Diectomis fastigiata (Fugulu), Dandandé, Soumbala, Boyale, Penisetum spp. These plants indicate fallow is ready for fonio production.

Few soft iron nodules below 60 cm in light brown matrix

Site IX Pit 2: M. Bary's nursery. Pit was on site of previous vegetable bed. The topsoil is constantly stirred to destroy weeds and termite trails. Weedy vegetation stirred into the soil.

—	A	LOAM
20 —		
	B	Silty-Clay Darker, elluviated organic matter; well-formed humus distributed throughout. No evidence of nodules or mottling
50 —		
60 —		Sample B from 50-60 cm depth

Site IX Pit 3: M. Bary's orchard. Pit dug under influence of drip line of four orange trees. Trees reportedly received manure for 17 years.

Sample A from 0-20 cm depth

Clay loam

Dark brown through whole profile; no nodules or mottles down to 60 cm.

Clay

Sample B from 60 cm depth

Continuous layer of indurated laterite at 60 cm depth in one of three sample holes, no signs of nodules or laterite in other two holes.

Site V Sallia-école Community Forest Plantation. One pit was dug in this grassy field which had been in fallow for two years before becoming a tree plantation in 1984. The predominant fallow vegetation was Pennisetum, (horsetail new plant), Wankoundai, a small, herbaceous legume and Ketchel. There was no sign of Chien dent. The topography is rolling and the plantation is on a gentle slope about 200 meters from the ridge. The site had been under fonio cultivation prior to the fallow period. There were no signs of influence of woody plants on soil of pit.

20	Sample A	loAm	reddish-brown, few soft nodules, some lateritic concretions of pebble size throughout profile.
40	Sample B	Silty Clay loAm	reddish-brown Soil is moist below 40 cm depth
60			Roots not evident below 60 cm depth
80	Sample C	Clay	light yellowish brown matrix, increasing number of iron nodules.
	Sample D	Consolidated lateritic gravel bed, gravel is semi-indurated and indurated.	

Site X Djibia Forêt Classée. This forest reserve was created in 1955. The vegetation ranges from a closed canopy of mature trees to open grassland. Two pits were dug under the forest canopy and one pit was dug in an adjoining grassy area. The site was on a slight to moderate slope. Khaya and Chlorophora were the dominant forest species. N'jobanm and broede were dominant grasses of grassy fallow. The soil depth varied from relatively deep (>100 cm) under the forest vegetation to shallow (20 cm) in the grassy area. A fourth pit was dug at the drip line of the woody vegetation to look at the soil at the transition line. No soil samples were collected for analysis from pit 4.

Pit 1: Soil under influence of forest trees and understory shrubs. Pit 1 was about 60 meters from the grassy clearing and is lowest one.

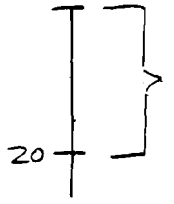
4	O layer, decomposed and partly decomposed plant matter	
	Sample A	Clay loam, dark, reddish brown; no mottles
54		dark brown, no mottles
77	Sample B	Silty clay, mottles at 77 cm depth; soft iron (red) nodules, matrix grades from yellow brown to grey with increase in depth.
107	Sample C, white sandy lens; compacted with no soil.	Woody roots to sandy layer at 107 cm depth no organized lateritic bed above sandy lens.

Site XI Pit 2: Soil under influence of forest trees and understory shrubs. Pit 2 was dug about 30 m. from edge of clearing and is a little higher than pit 1

4	O horizon		
	Sample A	Clay	Dark reddish brown
60			
	Sample B	Silty clay	Brown
82			
	Sample C	Silty clay	mottling, few soft red nodules in brown to light brown matrix.
110			roots to bed
	Indurated gravel bed		

Site XI

Pit 3: Grassy fallow predominated by N'jobahm and broede. Both grasses reportedly indicate that field would support fonio but not corn. The pit was dug in an area bordered by the forested area of the first two pits and a scrubby fallow on shallow soil. Rock outcroppings dominate the landscape below the sample area. Pit 3 was about 40 meters from pit 2 and about the same level. Teli (*Erythrophleum guineense*) were planted on the pit 3 sample area in 1984. It will be valuable to monitor the progress of the trees on the shallow soil as well as the influence of the vegetation on the soil.



Sandy loam Strong brown (but lighter than soils from sample A of pits 1 and 2.

Consolidated bed of yellow and red striped lateritic concretions

Pit 4: Drip line of forest species adjoining grassy fallow. No soil samples collected for analysis. Same level as pit 3

non-consolidated bed of loose, lateritic gravel; water table at 50 cm. (over bed)

Site XII Tapade and Fonio Field of Timbi-Medina Farmer. Samples were collected from topsoils within a tapade and nearby fonio field. Both belonged to one farmer and were located 70 metres from each other. There were no topographical influences that differentiated one site from the other. The farm is owned by Djallo Sallo and is located just outside of Timbi-Medina.

Site 1: The tapade beds are within the family concession and extend from the areas adjacent to the houses out to the concession fences. The concession is about .5 ha and the beds cover a little less than half the area. The older beds were raised about 15 cm above the ground level while newer ones rose to only a few centimeters. ~~Polyculture and relay cropping were the rule~~. The following crops were growing or had been harvested: manioc, corn, taro, sweet potato, gumbo, peanuts and cotton (one bush). Fruit trees and tall grassy fallow occupied the remaining soil. Polyculture and relay cropping were the rule. Corn, manioc and taro were found on the same bed but were harvested at different times of the year. All beds had at least one crop at varying levels of maturity. The topsoil appears to be constantly stirred. Weeds and plant residues are turned under. Household refuse and ashes are continually added to the top. Animal manure is brought in. Straw is sometimes spread under and around crops to control weeds. Chickens run in the beds stirring the soil for insects. No signs of termites were seen. A tethered sheep browsed the grassy fallow.

Several samples were collected from the top 12 cm for soil analysis. The soil was dark reddish brown and contained decomposed and partly decomposed vegetative matter

Site 2: The fonio field was well established and devoid of any perennial vegetation. Djallo Sallo, the farmer, said that the average rotation cycle includes three years of cultivation and four years of fallow. The soil was reddish brown.