Semi-Arid Food Grain Research
and Development Program

Farming Systems Unit
F. S. U.

OUA/CSTR - Joint Project 31
Contract AFR-C-1472 between
USAID and Purdue University

Document Nº 6

Elon Gilbert

DRAFT

FOR INTERNAL USE

S A F G R A D

ROCK PHOSPHATE FERTILIZER IN UPPER VOLTA

PART 1.: PRELIMINARY REPORT ON POLICY IMPLICATIONS OF CEREAL YIELD RESPONSE CHARACTERISTICS

Dr. Paul Christensen, Agronomist
and Chief of Party

SAFGRAD/FSU
B.P. 1783

Ouagadougou, Upper Volta

SEPTEMBER 1981

1. INTRODUCTION

1.1. The Objective of the Report

This report has as its underlying premises that the effect of the application of rock phosphate fertilizer mixtures on the farming system is different from the effect of the application of soluble conventional fertilizers with the same nutrient content on the same system, and that the nature of the difference itself may change with rainfall and soil characteristics. Most of the report is based on a subjective synthesis of information concerning the characteristics of these differences. This information was gleaned from experiment station reports, reports of fertilizer projects, conversations with other researchers, and background information on the physical characteristics of the fertilizers and soils. Because of the subjective nature of the synthesis, the conclusions should not be taken as having been proven. The report is presented because the author has observed a need for interim understanding of the differences between the characteristics of the rock phosphate based fertilizers and soluble the conventional fertilizers in the making of rural development policy in Upper Volta.

1.2. The Economic Environment of Central Upper Volta

The major argument for the use of rock phosphate fertilizer rather than soluble phosphate fertilizer is that a larger proportion of its total cost would be spent in Upper Volta, and that its total production and delivery costs can be kept low.

The proof of both of these assertions lies beyond the realm of farming systems research. The importance of local cost of fertilizer will be outlined, but the major thrust of this paper is to point out the differences in profitabilities of different fertilizer application strategies for central Upper Volta.

Installing a program of increased cereal production based on imported fertilizer usage is particularly problematic form the point of view of the economic environment. The cereals produced are not intented for export. Thus, to achieve balance, one would have to envision a sort of

.../...

triangular trade in which fertilizer would be imported for sale to farmers, who would produce grain for sale to a third group, who would in turn produce something for export , permitting the import cost of the fertilizer to be paid. Creating a system of increased cereal production based on a locally produced fertilizer would be conceptually simpler. The manufacturing and commercial sector would trade fertilizer along with other goods and services for cereals from the rural sector. Because Upper Volta lacks a cheap source of energy for fertilizer production, this simple domestic system is impossible. All fertilizer production in Upper Volta will require imported inputs. In reality, local fertilizer production would be a hybrid system, in which farmers would use the locally produced fertilizer to produce for both the local and the foreign markets, and would use their income to pay both the domestic and foreign fertilizer production costs. The urban sector of the country would produce fertilizer and would market the export crops. Local fertilizer production capacity and distribution would both enable the rural sector to produce a surplus, and enable the urban industrial sector to provide a service with which to earn the income to pay for their consumption of locally produced cereals. The use of some of the locally produced fertilizer for the production of cash crops for export would pay the import costs of the materials for fertilizer production.

1.3. The Cereal Production Environment

In the central portion of Upper Volta, soil characteristics vary with the location of the soil in the toposequence. The lowland (bas-fond) soils are commonly heavy clays which are relatively rich in phosphorous and have relatively good exchange capacities. These soils frequently have physical characteristics and drainage problems which make them difficult and expensive to cultivate. The saturated lowland soils are used for rice production, and the heavy soils located next to the saturated soils are used to produce late, photoperiod sensitive sorghum. On the slopes, one normally finds gravelly soils which may have quite good moisture holding characteristics if the laterite lager has broken down, or poor moisture holding capacity, if they are over laterite rock. In either case, phosphorous is likely to be the limiting nutrient for plant growth. Nitrogen may limit plant growth or not, depending on the organic matter status of the soil, and therefore on its history. Higher up on the toposequence there are

frequently shallow sandy-clay soils of poor structure. They are also usually deficient in phosphorous, and may or may not be deficient in nitrogen, depending on their histories.

The gravelly and sandy clay soils cover much larger areas than the heavy soils, and are therefore much more important in crop production. The concentration of plant nutrients (nitrogen and phosphorous) in these soils are low, and their moisture retension capacities are poor; but they can be improved. This is evident from the yields of garden plots around the houses where household wastes and animal manure are commonly applied, and from the superior plant growth on termite hills.

Thus, one can divide cereal production in the central portion of the country into 3 categories:

1. Lowland areas where production is limited by soil management problems and nitrogen,
2. Improved upland soils where production is limited by availability of animal manure, and
3. Unimproved upland soils where production is limited by low moisture retension capacity, low phosphate content; and finally, low nitrogen content.

The farmer's traditional strategy for cereal production on these latter fields is to accept low yields and to try to cultivate large areas. Thus, the factors limit the areas which can be cultivated, and therefore limit the production from these unimproved upland fields. The factors limiting the total area which a man can cultivate are the ability to weed the area, and the ability to plant the land in a timely fashion before it is time to start weeding.

1.4. Two Cereal Production Environments in the Unimproved Upland Soils

Physical responses have been specified for two classes of environments in order to simplify discussion of the profitabilities of fertilizer mixtures based on rock phosphate. The first environment

.../...

corresponds to higher rainfall and to better soil moisture retension capacities. The second class corresponds to lower rainfall and poorer soil moisture retension capacities.

The division of central Upper Volta into only two environments is inadequate for the purpose of making recommendations to farmers, but it will be shown, that even this simple division has important implications for the way in which rock phosphate needs to be distributed to the farmers. It is the nature of the distribution system for rock phosphate which has become the policy question to be answered. Thus, the simple division is both pertinent and useful.

1.5. Phosphate Fertilization in the Unimproved Uplands

Phosphorous is the first limiting nutrient in the low fertilility upland soils, but given the traditional strategy of extensive cultivation, its availability may not be the first economic constraint to production on these soils. No matter how important phosphorous nutrition may be in the long term, if one is to build on the traditional system in a step-wise fashion, phosphorous fertilization must be accompanied by good weeding and timely planting. Good weeding and timely planting will allow farmers to actually achieve yield increases promised by improved soil nutrient status. This weeding constraint precludes a general change to the practice of preplanting plowing for fields using an extensive production strategy, and limits the possibility for incorporation of the fertilizer into the soil. This in turn limits the response which one can expect from the use of any fertilizer under extensive production conditions.

What then is the justification for utilizing fertilizer in the extensive cereal production systems, given that it is feasible to upgrade the physical characteristics of many of these soils to the point where they can be cropped intensively, and to increase the return to fertilizer usage at the same time? The answer is that the return to the overall package of soil improvement techniques which is necessary for upgrading a soil to the point where it can be cropped intensively may be lower than the return to either the traditional system, or the use of fertilizer in an extensive system, even though the return to the fertilizer alone may be higher. The returns to any of the components of the intensive system

.../...

may be quite high in the presence of the other components, while the returns to the whole package may be relatively poor. Thus, one can expect farmers to expand the area where they cultivate intensively if and when they can acquire the resources to expand it at a reasonable cost. They will continue to cultivate on an extensive basis where the resources necessary for the transition from extensive to intensive production are not available at a cost which would justify their utilization.

2. LOCALLY PRODUCED FERTILIZER AND ITS ECONOMIC ROLE IN ENCOURAGING CEREAL PRODUCTION FOR LOCAL MARKETS

The author of this report regrets that because he is not an economist, the terminology used in this section will not be entirely convensional. However, the basic reasons for choosing to use rock phosphate fertilizer are largely economic, and some explaination of them is required.

2.1. The Necessity for Cash Flow Balance Between the Modern, Rural and Foreign Economics

It has been pointed out that increasing cereal production in Upper Volta will depend on increasing farmers'investment in agricultural production activities. The kinds of investments which farmers make currently are largely internal. They use labor, their principle resource, to clear fields, to build granaries, and to make other improvements which help them to produce more. These investment activities are relatively inefficient because the farmers do not have access to the tools, materials, and education which would make their work more efficient. In order to get the materials for raising their efficiency, they need to either have money, or to have the prospects of getting some (so that asking for a loan would be logical).

Currently, the government of Upper Volta would like to encourage farmers to produce more cereals. These cereal production increases would be for consumption in the urban centers and in certain grain deficit areas. The government would like to encourage farmers to increase their sales of grain and would like the urban economy to be able to purchase this grain. However, most of the goods which farmers want to buy are currently imported. Thus, the urban economy does not offer enough to the cereal producers to encourage the cereal producers to increase their cereal production. When they can produce agricultural products for sale, they tend to prefer products which can be exported, even though such exports may not conform to the governement's policies or to the wishes of the urban sector.

The modern sector of the Voltaic economy is in the position of needing to offer more in exchange for the cereals which they would like to purchase. One service which they could feasibly provide would be the production and distribution of rock phosphate fertilizer. This would benefit both sectors because it would increase the farmers' cereal production to the benefit of the cereal consumers, increase the farmers' production of exportable cash crops, to his own benefit, and simultaineously increase employment in the urban (or modern) sector by employing people in the distribution of rock phosphate fertilizer and in the commercialization of the export crops.

One way to state the advantage of the production and use of rock phosphate fertilizer is that it raises the productivity of the other resources in both the urban and rural economies. It does so by more efficiently employing urban resources while raising the absolute productivity of the entire rural economy.

At the national level, the need to produce increased amounts of cereals is important, but the increases are relatively small when compared to the total cereal production. In very approximate figures, about 2,200,000 ha of sorghum and millet are grown annually in Upper Volta. These fields produce about 400 kg of grain per ha for a total of about 880,000 tons of sorghum and millet. The national cereal deficit can be estimated at 50,000 tons, 6% of the total sorghum and millet production and equivalent to only 23 kg per ha.

Given the yield increases projected below, such a deficit could be eliminated with the use of 25 - 50,000 tons of rock phosphate, depending on the types of soils on which it would be used, and how well it was applied. The production of this quantity of ground rock phosphate is entirely feasible.

The amounts which would actually be used if the substance were available to the farmer would depend on the balance in demand for export crops and demand for crops for urban consumption, depend on world prices, and the ability of the modern sector to organize the commercialization of both kinds of products. Most of all, the amounts would depend on the efficiency with which the material can be distributed. If the costs are too high, or the deliveries are not on time, usage will not attain the levels necessary to have an impact on the national food deficit.

.../...

One can describe these conditions under which the rock phosphate commercialization would not suceed (and they are not too different from the current situation) by saying that the modern sector will have priced itself out of the market for this service to the rural sector. The rural farmer will prefer to market his services to the outside world through migration (for labor) or through cladestine exports, in order to purchase the imported products which he wants.

The desirable situation is a balanced situation in which modern sector services, including phosphate distribution and crop marketing, become more efficient and allow the farmers' production for both domestic and international markets to increase at the same time. The rising productivity following the use of rock phosphate fertilizer would increase the productivity of other imported inputs under these conditions and improve the country's ability to produce for the world market, and to import farm inputs in larger quantities.

2.2. An Explaination of the Reason for the Choice of Rock Phosphate Production in Terms of Relative Advantage in International Trade.

Countries trade in commodities for which they have a relative advantage. "Relative" is the important word in the sentence. The advantage need not be absolute. For example, even though it might be relatively expensive to produce cowpeas or cotton resources required in other countries, if these crops can be produced realitively cheaply in comparison to the cost of production of a certain bicycle part in Upper Volta, then Upper Volta will export cowpeas and cotton and import the bicycle parts from a country where production of cotton and cowpeas is relatively more expensive compared to the cost of production the bicycle parts.

If a country has very few resources, it is to a country's relative advantage to use any resources it has, to reduce its cost of production for the goods for which it has a relative advantage in international trade. The fact that the productivity of the resource may be relatively low compared to its productivity in another country or the productivity of similar materials may not be relevant. It only need be relatively, not absolutely, productive.

.../...

The factor which can limit the applicability of this principle is transport cost. Thus, there is an economic reason to suppose that the limiting factor in the utility of Voltaic rock phosphate is not its poor physical characteristics (low solubility), but the high cost of transporting it, and one can suppose that its utility will be greatest where transport cost can be kept lowest.

3.0. BENEFITS OF THE USE OF ROCK PHOSPHATE AS A FERTILIZER IN THE SHORT AND LONG TERMS.

3.1. The Physical Characteristics of Rock Phosphate and Other Phosphate Fertilizers which Determine the Nature of Their Yield Responses Over Time

3.1.1. The Soils of West Africa and Central Upper Volta and Their Phosphate Response Characteristics

The dominant characteristic of West African soils is that the land surfaces on which they have been formed have undergone heavy rainfall and leaching of nutrients from the soil in the past. This is particularly true of the upland soils. This leaching resulted in removal of phosphorous, calcium, and other important plant nutrients, and in the formation of soil types which are not conducive to the retention of soil nutrients.

In the semi-arid tropics this process has stopped with the passing of the heavy rains which had produced it. The depletion of phosphorous and calcium when the soil is acid is due to solubilization of the soils phosphorous and calcium. The acidity of soils through geologic time depends on the nature of the rock from which it was formed. In central Upper Volta most soils have been formed from granite. Granite, being an acid rock, has a tendency to give rise to acid soils. Thus, the soils of central Upper Volta have a particular tendency to be both rather acid, and also low in phosphorous and calcium.

When the bush is cleared and burned and farmers cultivate the land for a number of years, the stocks of plant nutrients from the soil organic matter, and from the ashs of the original cover, are depleted. Phosphorous is the first plant nutrient for which this depletion generally becomes a limiting factor in plant growth. Phosphorous deficiencies tend to become the first limiting factor in production on cultivated lands. Farmers' production systems tend to be organized around ways to manage any phosphorous containing manures which they may have available, and to be organized around crops which can produce most efficiently where available soil phosphorous levels are low. Millet is able to produce where the available phosphorous concentration is relatively low.

.../...

Although phosphorous deficiencies are widespread in central Upper Volta, they are not universal. The difference between the available phosphorous concentrations for newly cleared fields and for bush fields has already been cited. This difference should not be over emphasized, since the bush ecosystem growth (and even the growth of the animals that are in it) may be limited by phosphorous availability, and good responses to phosphorous can be obtained on newly cleared fields.

Another common factor in the variation in responses to phosphorous is the location of a particular soil in the toposequence. In the lowlands (bas-fonds) soils are usually less acid. Because of impeded drainage and slower water movement, clays accumulate. The higher cation exchange capacities of these clays discourages soils acidification. The basic cations lost by the surrounding sloping soils tend to accumulate, as do the phosphates which have been leached away from the surrounding acid soils.

The fields which are normally manured each year are another important class of exceptions to the general rule of serious phosphorous deficiency in central Upper Volta. On manured fields, particularly the fields around the family compound, in contrast to the newly cleared bush fields, there is a possibility of building up really large reserves of phosphorous in the soil by applying more of it each year than one crop can extract. The existence of such fields does not diminish the importance of phosphorous fertilization. The phosphorous content of the animal manure used on these fields is relatively low, and on a parcel of land which had not been as heavily fertilized in the past, the other plant nutrients in the animal manure could be more productive if they were used with a phosphorous fertilizer.

The soils of central Upper Volta are not generally of a chemical composition such that soluble phosphorous in the soil would be transformed into insoluble components, which not be available to plants. In some soils found in the humid tropics, extreme acidity combines with high soil iron concentrations to create conditions where soluble phosphorous would be transformed into insoluble compounds in which the phosphorous would be

unavailable. Thus, the residue of both soluble and rock phosphate fertilizers tend to remain available for uptake by plants in subsequent years. There is variability in the availability of the phosphorous in the soil. Only very small amounts of it will be in the soluble form used by plants at any one time. The transformation of soluble phosphorous into less soluble forms insures that it will be possible to obtain growth responses to additions of soluble phosphate fertilizers, even in soils where residual levels of phosphorous are relatively high.

All phosphorous compounds, even soluble phosphorous compounds, are relatively immobile in the soil. In contrast, nitrogen compounds in the soil are quite mobile. Nitrogen compounds move toward the plant along with the water which it takes up. In order for the plant to obtain the phosphorous it needs, its roots must come in contact with the particles to which the phosphate ions are attached, and the plant must actively transfer the phosphate ions into the interior of these roots. The greater the concentration of the phosphate ions in the soil, the larger the amount of phosphate the plant can effectively contact and take up.

Similarly, the poorer the root growth, the more suceptible the plant is to suffer from phosphorous deficiency, and the more responsive it will be to the phosphate fertilizer in the soil mass that it does contact. The upland soils of central Upper Volta are not only low in phosphate, but poor in structure, and therefore plant rooting in them is usually shallow. Under these conditions, the problem of low phosphate concentration is aggravated by poor plant root penetration. Some of the ill effects of poor soil structure under low rainfall can be eliminated by phosphorous fertilization.

3.1.2. The Characteristics of Rock Phosphate and Soluble Phosphate Fertilizers in Use

In natural phosphates the phosphorous is chemically bound into calcium compounds. In order for the phosphorous to be transformed into usable soluble forms, these calcium phosphate compounds must react with the soil solution. They decompose chemically. The rate of these chemical decomposition reactions are determined by:

.../...

1) the size of the particles of rock phosphate,
2) the pH of the soil,
3) the concentration of phosphorous in the soil solution, and
4) the concentration of calcium in the soil solution,

The smaller the particle size, the lower the pH, the lower the phosphorous concentration in the soil, and the lower the calcium concentration, the greater the rate of decomposition of rock phosphate. In addition, the reaction only proceeds when the soil is moist, so that in terms of years the reaction proceeds faster in the areas where the rainy seasons are longer.

Soluble fertilizers move into the soil solution almost as quickly as they come into contact with it. The concentration of phosphates in the soil which can be achieved depends more directly on the quantities of fertilizer applied. Because the chemical decomposition of the rock phosphate depends on the concentration of phosphorous and calcium in solution, an equilibrium-level of phosphate concentration tends to be established in the soil as the rock decomposes. In the short term this equilibrium concentration will be lower for rock phosphate fertilization than the levels which can be attained through the use of soluble phosphate fertilizer. In the long run, the phosphorous applied in soluble fertilizer is transformed into less soluble compounds in the soil, which may be no more available than the rock phosphate. In the long run phosphate levels in the soil solution may be similar, assumming that applications of phosphate fertilizers do not continue.

Another substantial difference between the two kinds of fertilizer is the amount of calcium in them. Rock phosphate has a much higher calcium concentration than the cotton fertilizer commonly used in Upper Volta. The soils of central Upper Volta are low in calcium as well. The low level of calcium in the soil tends to increase the rate of decomposition of the rock phosphate fertilizer. Yield response to the calcium released may exist quite independently of the yield response to the phosphorous. In addition, the release of calcium from the decomposing rock phosphate will have a tendency to inhibit soil acidification (which is largely a bi-product of calcium loss) at least where the pH values are below 5.

.../...

Because the rapid solubilization of rock phosphate is promoted by low pH levels and by promoted low concentrations of phosphorous and calcium in the soil solution, concentrations which are well below optimum for plant growth, it can not serve as the only phosphorous source for very high yield systems. The additional time for solubilization, and the additional quantities of phosphorous fertilizers which would have to be applied to achieve really high yields, would seriously reduce the solubility of the rock, and render it less productive, where its productivity is measured by the increase in yield per hectare for each additional unit of rock applied.

The important role for the rock phosphate is in making limited yield improvement on the shallow upland soils of Upper Volta. Under these conditions, the principle factor limiting the practical utility of rock phosphate as a fertilizer is soil moisture and the amount of it which one can put into contact with moist soil. The practices used to incorporate the rock phosphate into the soil can be modified to reduce the importance of this constraint.

3.1.3. The Accomodation to Phosphate Deficiency of Traditional Production Systems in Central Upper Volta.

Within the traditional subsistance crop production system little phosphorous is lost. This is in marked contrast to the situation for nitrogen. In the traditional system nitrogen is volitilized and lost when nitrogen containing organic matter is left to dry on the surface of the soil in the traditional system. The relative importance of phosphorous, calcium and potassium vis-a-vis nitrogen, is demonstrated by the practice of fieldburning. The nitrogen wasted by this practice is apparently of less potential benefit to the farmer than the phosphorous, calcium and potassium released by the practice. Factorial fertilizer yield trials consistantly indicate that it is phosphorous which is the most important of these three elements for producing the first increments of yield increase.

Man not only alters the phosphorous cycle by burning the vegetative matter from fallows, and by burning crop residues, but by transporting phosphorous from his bush fields towards his compounds. This phosphorous

is in the grain which he harvests and takes home, in the stalks and hay which he takes home for his animals, and in the animal wastes which are moved toward the compound as the animals walk home in the evenings with full stomachs. Much of this movement is unintentional, but considerable choice is excercised by the farmer in deciding where large animals will spend the night, and where the accumulated manure of both large and small animals will be used in the spring, as well as in deciding where the household wastes will be used.

3.1.4. Timing Fertilizer Applications for High Return

Sorghum yield responses for rock phosphate based fertilizers and for soluble fertilizers, for three different patterns of application in time, and for three different levels of nitrogen application, are presented in Table I. These figures form the basis for an economic comparison of the relative benefits from different patterns of application in time, as well as the comparison of benefits from the different nitrogen levels and the forms of phosphate. Certain of the figures are taken from the results of widely replicated trials on farmers'fields in Upper Volta. The values of the responses to soluble fertilizers on good soils in the first year are from the results of three years trials with about 100 replications per year, observed by the National Fertilizer Service (FAO cooperative program of the Voltaic Direction des Services Agricoles (DSA)). The first year figures for rock phosphate responses on good soils are derived from the soluble fertilizer responses by assuming 60% of the soluble fertilizer yield response, as was observed in trials conducted during 1977 and 1978 by Phosphate Project of the Voltaic DSA.

The figures for succeeding years are much less well substantiated and frequently based on expectations rather than observations. They are therefore subject to discussion. The validity of the results presented here depend on the assumption that the relative magnitudes are generally correct.

Sorghum yield responses have been assumed to increase each year for annual applications. The magnitudes of the first and second year responses are based on observations made by the Phosphate Project. The responses for succeeding years are based on the assumption that the percentage increase will be smaller, and the assumption that the maximum yield increase attainable under current management practices is 450 kg/hec. The base yield is assumed to be 450 kg.

The data is even less complete for soils with poorer moisture retention capacities. A 4 year yield trial done by IRAT at Saria provides the most concrete data. Following the results of this experiment, the responses to the annual application of rock phosphate mixtures was assumed to increase annually by a uniform increment. The first and second year responses to application of rock phosphate without nitrogen are substantiated by observations in FSU trial data.

The residual effects are substantiated by IRAT data from the 60's. The magnitude of the residual effects have been scaled back to correspond to the 450 kg base yield. Recent results from the Phosphate Project also substantiate the magnitude of the residual effects, as do the general patterns of declining responses observed in long term experiments in temperate countries (Russell).

The benefit cost ratios calculated for the four year streams of income and expenses are presented in table 3 through 6. The only costs and prices included were those of the fertilizer and grain in Ouagadougou (all soluble fertilizers at 90 CFA/kg; rock phosphate at 30 CFA/kg; sorghum at 50 CFA/kg). Given that other costs are not included, all benefit cost ratios of less than 2.0 are not likely to be acceptable. The 30% interest rate gives relative benefits in the eyes of the small farmer, whereas the 10% rate is appropriated for national planning.

.../...

TABLEAU 1.

ACCROISSEMENT DE LA PRODUCTIVITE DU SORGHO EN KG/HA SUR DE BONS SOLS
POUR 2 FORMES DE PHOSPHATE, 3 NIVEAUX D'AZOTE ET 3 MODES D'APPLICATION

Engrais utilisé	1re année			2e année			3e année			4e année		
	Composition chimique (N-P)			Composition chimique (N-P)			Composition chimique (N-P)			Composition chimique (N-P)		
	0-25	15-25	35-25	0-25	16-25	35-25	0-25	15-25	35-25	0-25	15-25	35-25
Application annuelle												
- soluble	88	250	450	109	310	450	130	372	450	143	409	450
- PB + urée	58	165	297	81	231	415	105	300	450	130	372	450
Application bi-annuelle												
- soluble	88	250	450	52	52	126	120	343	450	70	70	150
- PB + urée	58	165	297	45	45	113	100	280	450	5	65	143
Application unique												
- soluble	88	250	450	52	52	126	30	30	30	18	18	18
- PB + urée	58	165	297	45	45	113	45	45	45	30	30	30

TABLEAU 2.

ACCROISSEMENT DE LA PRODUCTIVITE DU SORGHO EN KG/HA SUR DES SOLS MEDIOCRES POUR 2 FORMES DE PHOSPHATE, 3 NIVEAUX D'AZOTE ET 3 MODES D'APPLICATION

Engrais utilisé	1re année			2e année			3e année			4e année		
	Composition chimique (N-P)			Composition chimique (N-P)			Composition chimique (N-P)			Composition chimique (N-P)		
	0-25	15-25	35-25	0-25	15-25	35-25	0-25	15-25	35-25	0-25	15-25	35-25
Application annuelle												
- soluble	65	185	344	81	229	350	97	275	350	107	302	350
- PB + urée	25	49	80	50	97	160	75	145	240	100	193	320
Application bi-annuelle												
- soluble	65	185	344	38	61	93	88	253	350	51	76	110
- PB + urée	25	49	80	40	66	100	65	130	200	51	76	110
Application unique												
- soluble	65	185	344	38	61	93	25	25	25	20	20	20
- PB + urée	25	49	80	40	66	100	30	30	30	25	25	25

TABLEAU 3.

RAPPORT BENEFICE.COUT POUR LA PRODUCTION DU SORGHO SUR DE BONS SOLS A 10 % D'INTERET CORRESPONDANT A 2 FORMES D'ENGRAIS, 3 MELANGES D'ENGRAIS, ET 3 MODES D'APPLICATION

Engrais utilisé	Composition chimique (N-P)		
	0-25	15-25	35-25
Application annuelle			
- soluble	1.15	1.66	1.63
- PB + urée	1.81	2.37	2.12
Application bi-annuelle			
- soluble	1.58	1.75	2.07
- PB + urée	2.52	2.44	2.57
Application unique			
- soluble	1.72	1.68	2.17
- PB + urée	3.14	2.43	2.45

TABLEAU 4.

RAPPORT BENEFICE/COUT POUR LA PRODUCTION DU SORGHO SUR DES SOLS MEDIOCRES A 10 % D'INTERET CORRESPONDANT A 2 FORMES D'ENGRAIS, 3 MELANGES D'ENGRAIS, ET 3 MODES D'APPLICATION

Engrais utilisé	Composition chimique (N-P)		
	0-25	15-25	35-25
Application annuelle			
- soluble	0.85	1.22	1.26
- PB + urée	1.19	1.05	1.01
Application bi-annuelle			
- soluble	1.24	1.39	1.58
- PB + urée	1.67	1.37	1.22
Application unique			
- soluble	1.34	1.38	1.67
- PB + urée	2.08	1.39	1.14

TABLEAU 5.

RAPPORT BENEFICE/COUT POUR LA PRODUCTION DU SORGHO SUR DE BONS SOLS A 30 % D'INTERET CORRESPONDANT A 2 FORMES D'ENGRAIS, 3 MELANGES D'ENGRAIS, ET 3 MODES D'APPLICATION

Engrais utilisé	Composition chimique (N-P)		
	0-25	15-25	35-25
Application annuelle			
- soluble	1.09	1.57	1.62
- PB + urée	1.67	2.18	2.03
Application bi-annuelle			
- soluble	1.39	1.62	1.97
- PB + urée	2.16	2.20	2.32
Application unique			
- soluble	1.53	1.55	2.19
- PB + urée	2.44	2.10	2.18

TABLEAU 6.

RAPPORT BENEFICE/COUT POUR LA PRODUCTION DU SORGHO SUR DES SOLS MEDIOCRES A 30 % D'INTERET CORRESPONDANT A 2 FORMES D'ENGRAIS, 3 MELANGES D'ENGRAIS, ET 3 MODES D'APPLICATION

Engrais utilisé	Composition chimique (N-P)		
	0-25	15-25	35-25
Application annuelle			
- soluble	0.81	1.16	1.25
- PB + urée	1.04	0.92	0.88
Application bi-annuelle			
- soluble	1.02	1.28	1.50
- PB + urée	1.38	1.14	1.02
Application unique			
- soluble	1.10	1.25	1.55
- PB + urée	1.53	1.09	0.92

The tables 3 through 6 indicate that one can achieve reasonably high benefit cost ratios with soluble fertilizers either by using high rates of nitrogen (urea), or by distributing these fertilizers over time to allow maximization of the benefits from the residual effects. The adoption of the high urea application rate alternative is of course associated with high cost and therefore associated with a high risk of loss. Using annual applications one cannot attain a benefit cost to ratio of 2.0 using soluble fertilizers at any rate of nitrogen (urea) application. This would not have been true if the 450 kg/hec. maximum response restriction had not existed, and substantiates the assertion that the profitability of soluble fertilizer use depends on improved crop management and maintenance of very high yields (1500 kg/hec.). The figures indicate that the current farmers' practice of distributing available fertilizer over several fields in alternating years is indeed more profitable given the existence of a yield plateau at 900 kg/ha.

For poor soils, all mixtures of rock phosphate plus urea have better benefit to cost ratios than soluble fertilizers. For poor soils soluble fertilizers are not acceptable under any of the applications patterns. Only single applications of rock phosphate (once every four years) proved to have a benefit to cost ratios of more than 2.0,and this was subject to the condition that the future benefits are not depreciated to nearly zero at high interest rates. This has important implications for extensive cereal production as will be indicated in the following section.

For poor soils it should be noted that by increasing levels of nitrogen application one will decrease the profitability of using rock phosphate mixtures,while increasing nitrogen application rates will increase the profitability of soluble fertilizer responses. This difference has discouraged agronomists from recommending rock phosphate fertilizer use in Upper Volta because the agronomists have usually been interested in the high yield levels possible with high rates of nitrogen application. The poor nitrogen response can be overcome by using massive doses of rock phosphate (500kg/ha) in the first year. Such applications do dramatically increase the response to nitrogen, but only at the cost of decreasing the benefit per unit weight of the phosphate itself. Such applications may very well be economic for export oriented crops where high nitrogen rates can be justified, but probably will not be justified for domestic cereal production.

4.0. USE OF ROCK PHOSPHATE FERTILIZER IN EXTENSIVE AND INTENSIVE PRODUCTION

4.1. Improving the Productivity of Extensive Production sub-systems in the General Characteristics of the Extensive Production Sub-systems

4.1.1. The extensive production systems of the region have evolved in an environment where very low yields per unit area are to be expected. The farmers'strategy is to plant large areas. The need to plant large areas is reflected in the farmers'choice of their agronomic techniques. The principal initial constraint in extensive production within the traditional system is weed control. The amount of time available for hand hoeing determines the land area on which the farmer can produce crops effectively. In order to have more time available for weeding, farmers are anxious to plant early. Early weeding of major bush fields and the planting operations for some intensive crop production activities occur at the same time of the year and therefore compete for the man power available to the household.

Within this context, the farmers' perceived need is to be able to do more weeding, so that he can cultivate more land. The most cost effective means of doing this in the central zone is currently to purchase a donkey drawn cultivator or hoe. One observes that the donkey drawn hoe, "houe Manga", is the most popular animal drawn implement in the zone.

One has to plant in lines if one is to use the donkey drawn hoe to weed. The usual means of doing the planting operation is to remove all but the two outside teeth from the hoe, spread the teeth to a spacing of about 60 cm and mark lines in the field using the hoe, or to modify the hoe so that 3 teeth can be spaced at 60 cm. intervals and mark. The tooth passes down each mark twice where 2 teeth are used. The farmers derive an additional direct agronomic benefit from planting in this little furrow. The seedlings come up better because their roots are deeper. The roots will be in soil which remains moist longer. The little furrow funnels a certain amount of water onto the young plants.

One improvement on this system is to use a larger animal to pull the hoe and to mount a bar across the top of the hoe with 4 teeth on it. This speeds up the marking process. The farmer may be able to mark in both directions, leaving a criss-cross pattern in the field. Planting in this square grid allows him to eliminate almost all the hand cleanup after weeding with the animal drawn hoe. A large amount of hand cleanup has to be done when one uses the donkey drawn hoe only to hoe up and down the rows, not across them.

The extensive cereal crop production system does not currently use any plowing. Even where animal drawn plows are available, the farmers' preceived need to plant early discourages the farmers from using the plow in extensive cereal production. The yield levels are frequently so low that the absolute magnitude of the increases in response to plowing would not be justified in the farmers' mind, even if these were reasonably large in percentage terms. In addition, he would be discouraged by the delay in his planting schedual which he would incur if he were to plow. Soil fertility and soil moisture retension capacity limit yield to such an extent as to reduce the economic return to plowing. Investment in the removal of these constraints to production is treated with the discussion of intensive production strategies.

Even in its fine ground form, the rate of decomposition of rock phosphate in the soil is very much determined by the moisture content of the soil. When the phosphate is applied to the surface of the soil and incorporated either by hand or with an animal drawn hoe it will only be mixed with the top 3-5 cm of soil. Even during the rainy season, this soil frequently will be dry. The rate of decomposition of rock phosphate will be lower where it is hoed into the soil than the rate of decomposition where it is plowed into the soil. In addition, there are less plant roots present at the surface because the upper part of the soil mass is frequently dry. When the rock phosphate does break down, the phosphate which is released will not be taken up as quickly as if it had been lower in the soil profile. The soil has a very high affinity for phosphates and very little movement in the soil can be expected. It would seem that these effects might exclude the usage of rock phàsphate as a side dressing.

.../...

The crop plants themselves are fortunately able to solve the problem, at least in the long run. Phosphate is taken up actively by the plant. If the phosphate is unevenly distributed in the soil the plant will selectively absorb phosphate from where the concentration is highest The plants will therefore transport some phosphorous down the roots system into moist soil, where it will be left in the decomposing roots at the end of the season in rather easily available forms. Insect activity in the soil is another potential source of downward phosphate transfer.

Most of the FSU on-farm experimental trials have used relatively shallow incorporation, (frequently less by intention than because of the difficulty of plowing in the fertilizer on small plots). The results of these trials are encouraging. There is no indication that the shallow placement of the phosphate is a barrier to its economic effectiveness.

In order to be applied in the extensive system the phosphate would have to be applied as a side dressing at the time of the first weeding. This is the first cultivation of the field, and it may not be productive to introduce a special cultivation for the purpose of incorporating the phosphate because of the problem of timming operations in the extensive production sub-system. Application of rock phosphate fertilizer as a side dressing provides even less favorable conditions for decomposition than the shallow preplanting applications which are normally tested. The difference may not be very great. The delay in application may not be as important as it would seem because the surface would be dry for much of the time between May 20, the time of planting, and June 20, the date of the first weeding. The first weeding would take place just at the time of the year when the rainfall normally becomes regular and when the phosphate rock can be effectively broken down in the surface soil.

4.1.2. Fertilization in Extensive Production Sub-systems

It was noted that less frequent applications were generally more profitable because of the benefit from residual effects of the fertilizer application. When discussing responses over time to fertilizer application and the optimal time of applications for maximum benefit to the farmer, in the case of soils with poor moisture retension capacities, less frequent

.../...

applications were the critical factor in deciding profitability because there were no other alternatives for attaining acceptable benefit to cost ratios. A large portion of the soils used for agricultural production in Upper Volta were of poor quality, and will not support the profitable transformation in to high yielding production sub-systems.

The acceptance of infrequent fertilizer applications indicates that yield increases will be small in absolute terms,even through they may be large in percentage terms. The average yield increase over the four year period for a single application of 100 kg of rock phosphate without urea is only 30 kg per year.

On good soils there is a real choice between intensive and extensive production techniques. High fertilizer application rates seem profitable and high yield levels are economically attainable. For soluble fertilizers, the profitability is contingent on very high nitrogen applications, and associated with both high risk to the farmer and problems with foreign exchange. The high benefit to cost ratios associated with infrequent rock phosphate applications in extensive production sub-systems are therefore a particularly attractive alternative even on relatively good soils. The mean annual increase in production over a four year period on good soil is not much greater than on poor soils even though the first year response is much better (44.5 kg/hec per year). One is maintaining an environment in which phosphorous is very much the limiting factor of production, assuring high yield responses to phosphate application on a per kg basis.

Good soils do have an advantage over poor soils in that biannual applications of rock phosphate seem highly profitable. Although the average annual yield increase under a strategy of bi-annual rock phosphate application is low, 67 kg/hec., the strategy has the major advantage of flexibility in that nitrogen responsiveness would be better than for less frequent applications. Because the phosphate levels in the soil would be relatively high, the farmers should be able to profitably add urea fertilization at any time when the higher risk seemed warranted.

Those who would doubt the national importance of a fertilization strategy which would only increase yields by 30 kg per year should consider the following figures. Upper Volta has approximately 2,2 million hectares of land under cereal cultivation. For purposes of simplicity let us assume that 2.0 million hectares (90% of the total) are used in the extensive production of sorghum and millet and that an application of 100 kg of rock phosphate would produce an average of 30 kg of extra millet per year as we have assumed for sorghum (at high yield levels the response of millet is markedly less than that of sorghum, but at low yield levels this is not true). The surplus cereals produced would be 60,000 tons per year for a national application of 50,000 tons of phosphate. The average cereal deficit for Upper Volta over the past few years has been on this order of magnitude. A program of rock phosphate application in extensive production has the potential of making a substantial contribution to the solution of Upper Volta's cereal production problem.

On poor soils rock phosphate suffers from the serious diaadvantage that the major yield response is in the second year. The benefit to cost ratio at higher interest rates is reduced substantially (2.08 for single applications at 10% verses 1,53 for 30%). This provides a major justification for some subsidy either on the cost of the fertilizer or on the cost of financing it. Possibly the easiest and most effective from of subsidy would simply be to subsidize the delivery of the fertilizer to the villages. This would be particularly effective during the introduction period, before the role of the rock phosphate in farmers' production strategy becomes clear to them. The nature and amount subsidies on fertilizer must of course be determined outside the farming systems research frame-work. The demand for cereals is a very important determinant, and cereal demand is not an integral portion of farming systems research.

The introduction of a major program of rock phosphate usage need not wait for the development of a source of funds for subsidy. The returns are sufficiently good on soils of good moisture capacity to encourage farmers to use rock phosphate even where they discount the future benefits at 30.%.

.../...

This is an appropriate point to interject a word of caution about pricing policy for rock phosphate fertilizer. 30 CFA per kg has been used as the price in all the calculations in this report. This is roughly 2.5 times the world market price for phosphate rock, and reflects the cost of fine grinding and the high cost of local transport. However, if volume production cannot be achieved, one will probably not be able to keep costs below this level. Success of the system depends on high volume usage. High volume would permit lower costs of distribution and commercialization. The same statement applies to the task of marketing the potential surplus. Thus, the major argument for subsidy is not to solve problems at the farmers'level, but to enable one to achieve the economies of scale necessary for national success.

Another word caution concerning the sources of the nitrogen and potassium for crop production is also appropriate. The assumption for the establishment of the yield increments is that these elements would not generally be limiting. Certain steps have to be taken to assure that this remains the general case. The traditional practice of intercropping cowpeas with cereals must be encouraged, as should the traditional practice of rotating peanuts with cereals. Crop residues should not be burned, as the nitrogen contained in then is lost in burning. The residues may be feed to animals and the manure recycled, or placed on termite hills to insure quick decomposition. Returns to such practices will increase as the level of phosphorous in the soil increases.

In summary, infrequent fertilization with rock phosphate fertilizer seems to be the only fertilization strategy worth considering for poor soils. On better soils there is a real choice as to whether one should use an intensive or extensive system. Even on good soil the extensive system has the advantage of minimum cost, low risk, high return, and little change in current cereal production strategy.

The poor returns for intensive cereal production do stem from the rather arbitrary maximum yield of 900 kg/ha (equivalent to a yield increment of 450 kg/ha in Tables 1 and 2). This figure was intended to show the limitations of Voltaic farmers' current management techniques.

.../...

The arguments presented here are not intended to indicate that Voltaic farmers should never practice intensive cereal production on areas any larger than those that they currently use. In the next section the transition to higher levels will be discussed, but it is important to realize that soil fertility improvement and weeding for extensive production rank before varietal improvement and plowing on the scale of importance of the techniques necessary for making the transition to intensive cereal improvement.

4.2. The Characteristics of the Traditional Intensive Cereal Production Sub-system in Central Upper Volta and Possibilities for Improving their Fertility

Nearly all families in the central portion of Upper Volta practice some intensive cereal production. Most of this intensive production is associated with the village fields and garden plots. The maize which is produced,is nearly always produced on an intensive basis, with large inputs of animal manure, ashes from the family cooking fires, and household refuse. Sorghum and millet are grown on an intensive basis on village fields receiving a complement of animal manures, etc. Red sorghum is very frequently found in the village fields. Frequently the villages are located high in the toposequence, and the soils are sandy or gravelly. The relatively early maturity of the red sorghum is an advantage here, because the moisture holding capacities of the soils are limited.

Another component of the families intensive cereal production is based on the existance of numerous termite hills in their fields. The termits bring up the subsoil which is chemically rich, and the termites collect organic matter from the surrounding area. When the old hills are knocked down they provide a fertile medium for plant growth, but they have poor physical soil structure. In order to make the soils of the termitehills permeable, the farmers pile stalks on the hills. This improves the chemical state of the soil as well as keeping the soil moist by aiding in water penetration.

No table of yield responses for the traditional intensive cereal production in such systems has been presented. The number of yield trials which have been carried out on this type of field is not great, and it is difficult to get figures on yield response values for them. In general one would expect yield responses similar to those obtained on experiment stations. The results of one experiment on such fields is presented in table 7. as an example.

Currently, when farmers have access to fertilizer they use it in this kind of intensive production. Frequently corn, and sorghum are intercropped with cotton on the very best fields. This combination allows the farmer a cereal crop for his own use, and a cash crop with which to finance the fertilizer. The total area of this intensive production is rather small. Only approximately 3% of the average farmer's fields are used for intensive production. On a national basis this would amount to 66,000 hectares. If production levels could be increased by 300 kg per ha from their already high level the total surplus produced would come to 19,800 tons. The annual cereal deficit for Upper Volta has been above this figure for several years. This indicating that a policy of fertilizing existing intensively cultivated fields will not be sufficient to alleviate the national problem.

There is reason to doubt the effectiveness of rock phosphate on fields which have been manured with animal manure and ashes for long periods of time. Under these conditions the pH of the soil and the level of phosphorous in the soil may have been increased to the point where the solubility of the rock phosphate would be rather low.

The physical response to the urea would still be rather good, but usage of urea alone would be a strategy involving a very high foreign exchange cost. It may be advisable to use a fertilizer strategy for the fields traditionally used in intensive cultivation which would include cash crops, such as cotton or tobacco.

Given the lack of information on these fields it is preferable not to speculate about them too much. It is fundamentally more important to consider the question of the possible expansion of intensive production into new fields, which have previously had much lower yields.

.../...

TABLE 7.

YIELD INCREMENTS (KG/HA) OF SORGHUM FOR TWO MANAGEMENT LEVELS

Management Practices	Village Fields		Bush Fields	
	Local Variety	E-35-1	Local Variety	E-35-1
Traditional	1247 + 0	1247 + 210	315 + 0	315 - 177
Preplanting cultivation; 100 kg/ha rock phosphate 40 kg/ha urea	1247 + 366	1247 + 521	315 + 581	315 + 440

4.3. Passing from Extensive to Intensive Production on Good Soils

On good soils the transition from extensive to intensive production appears to be not only feasible, but profitable as well. Annual applications of rock phosphate urea mixtures have benefit to cost ratios of more than 2, even when the income and expenditure streams are discounted at 30%. On the contrary, returns to soluble fertilizers do no allow annual applications of fertilizer, and therefore would not allow one to arrive at the 900 kg/ha average level which has been designated as the lower limit of the range of yields corresponding to intensive production. Economic returns to soluble fertilizers are contingent on improvements in crop and soil management permitting higher yield responses to the soluble fertilizers.

There are two main stumbling blocks to actually achieving intensive production using rock phosphate fertilizer. The first block is a physical problem or set of physical problems, and the second relates to the economics of the national cereal market. The first indicates that the expectations for yield increases on intensively cultivated fields may be unreasonably high over the long term, and the second that the cereal price outlook may be too high as well.

The reason why one may not actually be physical able to acheive the highest yield levels in the tables on a year after year basis is that other mineral deficiencies may develop. The first mineral nutrient deficiency which would probably appear would be a deficiency in potassium.

In establishing the tables of yield responses (Tables 1 and 2) potassium has not been mentioned. Within the four year time span described, and given the relatively low yields, potassium is unlikely to limit growth. That is, other management factors are more important in determining yield . After 5 years in intensive production, potassium deficiencies may start to limit responses to phosphorous and nitrogen. This would not happen with the soluble cotton fertilizer now on the market. This fertilizer was formulated with long term soil fertility maintenance in mind and contains adequate potassium.

.../...

Mixtures of rock phosphate and urea do not provide any potassium. The soluble complete fertilizers, such as the current cotton fertilizer, would perform better in the long run, and continue to maintain relatively high yield levels. Unfortunately, low profitabilities in the initial years would preclude their usage on cereals and the potassium would rarely be productive. One might speculate that farmers might produce intensively using the rock phosphate region for a few years and then allow the field to return into some sort of extensive production, retaining only the area for which the farmers' own supplies of potassium would support, or continue intensive production using the cotton fertilizer with potassium.

Soil acidification and the depletion of soil organic matter is another physical constraint which could limit the development of intensive production based on the use of rock phosphate urea mixtures, but as a block to intensification this would be less important than acidification in systems using soluble fertilizers because the acidifying potential of the rock phosphate fertilizer is smaller.

The economic argument against the viability of intensive cereal production is more conclusive, but it is important to realize that the arguments which are presented here do not apply to exportable cash crops, and would not even apply to cereals if they were to be exported.

The total area of good soils in Upper Volta is difficult to determine, but it is safe to assume that the area is sufficiently large to make it physically possible produce a quantity of grain several times the national magnitude of the national cereal deficit. If a large portion of the local farmers adapted an intensive production strategy and the surplus were not exported, the price of grain would fall to the point where fertilizer ceased to be economic. As the price of grain falls not only would intensive production using large amounts of fertilizer cease to be economic, but fertilization of extensive production on poor soils would cease to be economic. Only for relatively extensive production on good soils could the fertilizer continue to be used. Analytic treatment of these assertions would go beyond the scope of farming systems research, but the argument

.../...

indicates that intensive production of cereals using high rates of fertilizer has its dangers as a national policy. Intensive production of exportable cash crops on the better soils should have a much brighter outlook. Annual fertilizer applications and high nitrogen application rates would be reserved for cash crops for export.

The cropping pattern which is emerging in the South-Western area of Upper Volta shows these tendencies, even though rock phosphate does not form a part of the system. Large amounts of fertilizer are applied to the cotton. The cotton is rotated with corn or sorghum to take maximum advantage of the residual effects of the fertilizer. Growing cereals without nitrogen application on residual mineral nutrients left over after fertilized cotton is similar to growing cereals using rock phosphate alone.

Upper Volta's relative advantage in agricultural production exists in using a resource, phosphate, and a production system within which that resource can be profitably employed without extensive changes in the system. The country does not have a particular advantage in intensive production of cereals using high rates of imported soluble fertilizers, and would be well advised not to risk too many resources in trying to encourage this type of cereal production.

5.0. THE ROLE OF PHOSPHATE FERTILIZER IN INCREASING RETURNS TO OTHER AGRICULTURAL PRODUCTION TECHNIQUES

The traditional farming systems of Upper Volta reflects the phosphate deficiency of its soils. Phosphorous is neither volitalized nor leached, and thus is only lost from the system when it is physically removed, i.e. when grain is sold or when soil is washed away by erosion. Plant recovery rates of phosphorous are low, and if applications of even small amounts continue over time, phosphorous levels will, almost irreversibly, build up. With the removal of phosphorous as a constraint to plant and animal growth, the production system can be expected to change to accomodate its new resource base.

To derive the maximum advantages from this transition the farmer should be told in advance what to expect. Returns to other plant nutrients will rise. Thus, he can expect higher returns to additional manures which can be generated on the farm or in the household. The incentive for keeping more animals will increase because of the increased productivity of their manure. The incentive for improved manure conservation will increase because the nitrogen content becomes much more important (only the nitrogen is lost when animal manure is left to dry in the sun). For relatively high yielding fields, which have been in production a long time, the farmer may be able to get profitable responses to ashes and thus have more incentive to spread them further than the family corn field. Finally, the returns to application of imported urea increase dramatically, at least after a certain quantity of rock phosphate has been applied and some time has passed.

As all forms of phosphate are essentially immobile in the soil, except when actively transported by plants returns to improved cultivation may be markedly increased. Together with the increased response to animal manure, this makes the incentives for the adoption of animal traction much greater. The opportunities for plowing are limited within the traditional extensive production system. The need to plant early is very great where the areas to be weeded are relatively large, but nevertheless

families would seem to have the time available to plow about 1 hectare of land. The crops left to be planted at the time when plowing can be done are peanuts, corn, and some red sorghum. The opportunity provided by plowing in rock phosphate for peanuts is greater than what would be indicated by the response of the peaunuts themselves. Peanuts are always grown in rotation with millet or sorghum and the residual effects of the phosphate is markedly improved by deeper plowing. As has been stated, the response to rock phosphate on traditional corn plots may not be good because their soils may no longer either be low in phosphorous or be acid enough for the rock phosphate to break down quickly. The late planted red sorghum, and other photoperiod insensitive sorghum, planted on village fields receiving limited amounts of animal manure, may be quite responsive to plowing and rock phosphate in combination.

In terms of improved varieties, the interaction with the rock phosphate may not be so important. The yield levels attained in extensive production are too low for the improved varieties to perform well. In the second phase where rock phosphate has its impact on the levels of other components in the crop management equation, the contribution of varietal improvement will be much greater.

6.0. SUMMARY

Compared to a system using imported soluble fertilizers the advantage of installing a cereal production system including usage of ground rock phosphate as a fertilizer, depends on the ability of the system to fullfill four basic criteria:

1. The ability to reduce the foreign exchange component of the cost of phosphate fertilizer production, so that the cereals can rationally be sold on the local market.

2. The ability to produce a reasonable yield response for both cereal and cash crops in both the short and long term, vis-a-vis the overall cost of supplying the ground rock phosphate fertilizer to the farmer.

3. The ability to produce a reasonable yield response for both cereal and cash crops, in both extensive and intensive production sale systems vis-a-vis the overall cost of the ground rock phosphate fertilizer.

4. The ability to increase the return to investment in other crop production improvement technologies (such as: improved weeding practices, other fertilizers, improved varieties, and plowing).

Rock phosphate can fulfill these criteria for some reasonably large area of Upper Volta. The geographic size of the area and the magnitude of the marketable surplus which can be generated depends as much on the efficiency of the distribution and marketing system or systems which will handle both the fertilizer and the marketable export crops and grain, as it depends on the physical response characteristics of the ground rock phosphate itself.

The unique role of phosphate fertilization in West African agricultural development is imbedded in the ability of both local rock and imported soluble fertilizers to fulfill the second, third and fourth

criteria listed above. Phosphate deficiency and its long term secondary effects on soil structure and chemical composition frequently limit vegetal production, not only on cultivated fields, but in the bush fallow as well. Phosphorous deficiency is so wide spread as to insure initial responses to rock phosphate applications in all but lowland (bas-fond) soils, and areas which have previously received large quantities of manure or fertilizer. The small portion of a rock phosphate application taken up by plants in the year of application insures substantial residual effects in subsequent years on savanah soils, where soil chemistry is not such that the phosphorous would be transformed into insoluble forms. The residual phosphorous left in the soil contributes to the ability of other sorts of production technologies to increase yield and increase their profitability.

The ability of phosphorous fertilization to produce yield increases in extensive low yield subsystems is particularly important to its ability to increase food production in Upper Volta. Food production in Upper Volta is not only divided temporally into current low yielding systems and future high yielding ones, but spacally into extensive subsystems, characterized by low yields, and intensive subsystems, characterized by much higher yields. One of the most important characteristics of phosphate fertilization is to be able to profitably increase the yields of the low yielding subsystems with minor changes in current technologies (even in the short term) without transformation of these extensive production subsystems into intensive subsystems.

Phosphate fertilization can increase the profitability of low yield portions of current production systems and increase the profitability of the transformation to more intensive production. Rock phosphate is particularly attractive because of the low total cost and the low foreign exchange component of this cost. Its residual effects would make its use an almost permanant improvement in the soil capital and agricultural production capital of Upper Volta.

-o-o-o-o-o-o-o-o-o-