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Experience with Food Crop Production in Five Major Ecological Zones

Stephen J. Carr
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Washington, D.C.
Abstract

This study draws together information on the technology which is available to small-scale farmers in Africa and assesses its applicability in the context of the financial, economic and managerial constraints which face rural households. It also draws on the experience of the World Bank through an analysis of the technologies which have been proposed for twenty-five projects in five different ecological zones. In each of these zones the study highlights a dominant constraint which has to be overcome if farmers are to increase their productivity without sacrificing household security.

A recurring theme is that technology does exist which can enable farmers to deal with such factors as timely planting and weeding and the provision of adequate plant nutrients, which together can bring about substantial increases in yields. All too often, however, there are factors outside the control of the farm family which render such technology impracticable. The paper highlights the need for greater sensitivity on the part of extension and research staff to the constraints which prevent farmers from adopting the techniques which they are promoting. In a final section the paper summarises specific challenges to research and opportunities for extension with regard to the most important factors determining crop productivity.

The paper has primarily been produced as a reference work for agriculturalists and economists responsible for planning, executing or supervising crop-related activities in Sub-Saharan Africa. It deals with the eight most widely grown crops in the region and focusses in some detail on the applicability of new planting material, agronomic practices and use of purchased inputs to the actual situations facing farm families. Its overall conclusion is that the challenges facing farmers, extension staff and research workers are not insuperable but that the last two groups should be well aware that there is still a lot more work to be done to produce new technology which is really applicable by the majority of small-scale farming families.
Acknowledgements

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Technical Note on the Symbols P and K

Throughout this text the letters P and K have been used to symbolise the oxide form P2O5 and K2O. It was originally intended to refer to the elemental form but it became apparent that in most project documents the calculations were based on the oxide form, and it would have created some confusion to transpose these into the elemental form in the quotations used in this paper. For the sake of uniformity the same pattern has been followed throughout the document.

Note Relating to Quoted World Bank Documents

This paper makes reference to a range of World Bank staff appraisal reports and to some project completion reports. All of these are restricted documents and are not available for reference by the general public.
The plans and decisions relating to agricultural development are increasingly being made by economists, financial analysts and administrators with little or no experience of the technologies of crop production. At the same time there is growing awareness of the fact that the impact of institutional and structural change on increasing agricultural productivity will be seriously limited in the absence of technologies which are attractive to farmers and help them overcome their constraints. When people do not have detailed knowledge there is a natural tendency to resort to generalisations. This is happening in the development community which is divided over the issue of the availability of technology to bring about substantial increases in smallholder crop production in Sub-Saharan Africa. One body of opinion maintains that relevant technology is readily available off the shelf and the only need is for improved services for information and input delivery. The other school holds that research has failed to provide relevant technology and that no progress can be made until that situation is rectified.

This paper moves beyond such generalizations and provides a detailed analysis of the availability of applicable technology to deal with the dominant constraints facing farmers in a range of different climatic zones. Although its primary audience is intended to be non-agriculturalists who have to make plans and decisions about farming, it will also be a valuable resource for technical staff who have not had personal experience with a particular region or crop. It draws on a lifetime of the author's first-hand experience with African smallholder agriculture and focuses on the applicability of technology to families with limited resources rather than on the simple issue of availability.

In addition to the description of the various techniques which can be used to overcome farmers' constraints, the paper takes a critical look at the World Bank's own experience with bringing about technical change. This is done through an analysis of the technical content of twenty-five recent projects in different parts of Africa. This adds a valuable dimension to the document and provides planners with an opportunity to judge their proposals against the experience of the past in a condensed and convenient manner. We have learned some painful lessons in recent years about the pitfalls of lending in situations in which there was a lack of understanding of the specific requirements and potential of local farming population. This paper is intended to address some part of that deficiency and should not only provide factual information but the stimulus to achieve greater technical excellence in agricultural planning.

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Africa Region, World Bank
INTRODUCTION AND SUMMARY

1. This paper is intended to be used as a reference source by those who have to make decisions on the availability of technology to increase farmer productivity or security in a given region without the benefit of lengthy experience of the agriculture of the area. It is seen by the author as a first "quick and dirty" attempt to provide a possible model for more detailed work with greater resources than have been allocated to this study. In this initial paper the region under review has been divided into just five zones, and only those annual food crops with a recorded area of more than two and a half million hectares in Sub-Saharan Africa have been included in the study. Because it is intended as a reference document there are inevitably repetitions. In addition to a summary description of the availability and applicability of technology there is a review of the technical content of projects supported by the World Bank in each region. This information is intended to provide a quick guide to past efforts and to give an indication of the suitability of a particular technology which has already been attempted.

2. Because there has been considerable misunderstanding of the phrase "available technology" this manual has focussed on viability as well as availability. Technology is available to increase the area cultivated through the use tractors. Yields can be raised in many situations through the use of fertilizers and pesticides. Weeds can be controlled by the use of herbicides. The technologies are available to overcome many of the farmers most pressing constraints, but there are all too often economic and financial factors which render this technology impracticable for smallholders in remote rural areas. Many people can readily see that tractors are an available but not a viable technology for small scale African farmers. What is less well appreciated is that other, apparently simpler technologies can be equally inaccessible. Timely cultivation, planting and weeding can all have a striking impact on yields. The knowledge and the technology are readily available, but for many families which face severe labour constraints at critical points in the farming year that technology is often not applicable. The point is sometimes made that the existence of wide differences in production practices and yields within one community is evidence of the availability of technology for that area. This is an accurate statement of general fact but it tends to mask the difference between availability and applicability, because it underestimates the wide disparities in family resources between members of a single community. A technology which is practical for one family may be quite beyond the capacity of a neighbouring household.

3. There is also a timing factor regarding the availability of technology which is in danger of being overlooked. An innovation which was financially attractive to farmers at one point in time, can be quite unattractive, as a result of a change in price ratios. A yield enhancing practice which was applicable to a family at one point in its development (e.g. with a number of teenage children at home) may be impracticable a few years later when family circumstances change. The same is true of a whole
community for which a technology which has always been available (e.g. swamp drainage) only becomes attractive at a particular time as a result of demographic change. Correct timing of the introduction of such an innovation will make the difference between acceptance and rejection.

4. African farmers have made major changes to their farming systems in the recent past. The adoption of newly introduced crops such as maize, cassava, sweet potatoes, cotton and groundnuts involved changes in farming patterns, crop mixes, cultivation practices and the allocation of labour between the sexes. Farmers demonstrated their capacity to experiment and innovate on a remarkable scale. That capacity has not diminished, but some of the challenges which they now face are more complex and call for a broader mix of skills to meet them. Research workers have at times underestimated that complexity so that new technology offered to farmers does not fully meet their needs. In consequence there are times when agricultural officials believe that technology is available and blame farmers for the lack of adoption, when in fact what is required is more penetrating research. The constraints outlined in this paper do not present insuperable obstacles, but they do provide a challenge to more intensive effort rather than a belief that all that is required is for farmers to accept the technology being presented to them.

Summary

5. Because this is primarily intended as a reference manual there is a limited role for a summary and it will therefore be brief. The document covers five major zones in Sub-Saharan Africa and the eight most commonly grown annual crops. The paper identifies a major regional constraint in each zone and reviews the availability and applicability of technology to deal with that constraint. It then outlines possible technologies for each of the major crops of the area under the headings of planting material, field practices and the use of purchased inputs.

Section 1: The Humid Tropics of West and Central Africa

6. The major challenge to farmers and researchers in this zone is the maintenance of soil fertility in an area of severe leaching under annual field crop production. On compound farms the use of trees, organic waste and ash enables families to maintain continuous cultivation on a small area. The same does not apply to larger scale field production. In consequence the productivity of the major crops of the area, cassava, yams, maize and rice is often determined by soil fertility factors rather than just farm practices.

Section 2: The Sub-Humid Zone of West Africa

7. The major constraints on farmers in this zone are a shortage of labour at critical points in the farming year, a poorly developed infrastructure in thinly populated areas and soils which are by nature deficient in certain essential elements for plant growth. The area has been subject to tse-tse fly problems and so ox cultivation is not widespread and in consequence tractors have often been viewed as an answer to farmers'
constraints. There have been considerable problems with this approach and few success stories. Maize, yams, cassava, sorghum, rice and groundnuts are all grown and the technologies for increasing their production are concerned with overcoming critical labour constraints and problems of soil fertility.

Section 3: The Sorghum and Millet Belt of West Africa

8. The availability of water for crop growth is the main constraint faced by farmers in this zone and this section focuses both on strategies now used by farmers to overcome that constraint and on possible alternative initiatives. Because of the uncertainties of this environment farmers are particularly concerned with security of production, and technologies which weaken their security are unlikely to prove popular. Sorghum, millet and cowpeas have been selected by farmers in this area over many centuries. They are often grown in mixtures and have a low yield of grain in relation to total plant growth. They present research workers with the considerable challenge of raising productivity whilst retaining the plants' ability to survive a harsh environment. The section describes past efforts to develop new technology and describes potential patterns for new initiatives.

Section 4: The Savannah Zone of Eastern and Southern Africa

9. This encompasses a diverse area which would be subdivided in a more comprehensive work. In the drier parts of the zone it is the low and erratic pattern of rainfall which determines the farming system and, as in West Africa, the most appropriate technologies are those which address that constraint. In the wetter areas farmers are constrained by labour shortages at critical periods, and the practicability of a technology is judged on the basis of the degree to which it addresses that constraint. Sorghum and millet are the main crops of the drier areas and there are some hopeful developments in the breeding of new material for this zone. Maize is important in the wetter areas but its yields are often lowered by mid-season drought and the viability of technology for improving on production has to be judged against this background.

Section 5: The Highlands of Eastern Africa

10. This is one of the most fertile and well watered zones on the continent. It is also the most densely populated and the main constraint now being faced by farmers is a shortage of land. They are therefore looking for technology to intensify land use, which is also financially attractive and within the reach of family resources. A wide range of crops is grown in this zone but only two, maize and groundnuts, belong to the group being covered by this paper. The section therefore concentrates on the viability of available technology for increasing yields of these two crops per unit area of land at current international prices.
Section 6: A Summary of Some Priorities for Research and Extension

11. Technical options for increasing crop production mainly concern planting material, agronomic practices and the use of purchased inputs. In addition there are broader constraints of soil fertility and water availability which limit production. This section draws out salient points from the paper which highlight opportunities for extension and research services to offer farmers more appropriate help than they have sometimes given in the past.
1. THE HUMID TROPICS OF WEST AND CENTRAL AFRICA

Background

This zone has a population of about 95 million, over 20% of the total for Sub-Saharan Africa. It is however clearly divided into two areas with quite distinct demographic features:

(a) The West African forest zone which covers about 970,000 km² with a population of some 61 million and an average density of 63 persons per km²; and

(b) Central Africa which covers 3.51 million km² with a population of 34 million and a density of 10 persons per km².

Consequently, the need to intensify agriculture is arising at an earlier stage in parts of West Africa as compared to Central Africa and the timing and nature of technical priorities is different. One of the basic characteristics of the humid lowlands of Africa is the susceptibility of the soils to degradation, and the tendency for soil productivity to decline rapidly with repeated cultivation. This is obviously of more immediate concern in densely populated areas than in those with abundant land resources per head of population. An assessment of available, applicable technology has to distinguish between these two situations.

Sustainable Farming Systems

In the most densely populated areas of West Africa it is the maintenance of soil fertility which poses the greatest challenge to research and extension staff. It is also the level of soil fertility which determines cropping patterns and yields to a much greater degree than is the case elsewhere on the continent. There are four basic technologies in use to restore soil fertility for annual cropping systems, and farmers may combine more than one of these on their farms. These are:

(a) the use of forest fallow. This is the traditional technology and remains viable as a means of maintaining soil fertility where adequate land and labour resources are available. For a growing number of people it has ceased to be a practicable technology and is having to be modified;

(b) the use of organic manure. This is the technology of the compound garden and is capable of both maintaining and raising yields over long periods of time. It is dependent upon the importation of organic matter from outside the system and usually relies on further supplementation with wood ash as a soil ameliorant. Because of the high levels of mineralisation of organic matter in the wet tropics the system requires heavy and frequent applications and does not provide a viable technology for field scale crop production using only hand power;
the use of inorganic fertilizers. Heavy dressings of lime and inorganic fertilizer are able to slow down the rate of degradation on acid ultisols, but work to date shows that if fertilizer is the only input then yields decline after some years. A current recommendation in the high rainfall areas is given in Table 1:1:

Table 1:1 Recommendations for Annual Dressing of Nutrients to Maintain Continuous Cultivation

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime</td>
<td>1 ton</td>
</tr>
<tr>
<td>N</td>
<td>80 - 100 kg</td>
</tr>
<tr>
<td>P</td>
<td>25 kg</td>
</tr>
<tr>
<td>K</td>
<td>80 - 100 kg</td>
</tr>
<tr>
<td>Mg</td>
<td>18 kg</td>
</tr>
<tr>
<td>Cu</td>
<td>1 kg</td>
</tr>
<tr>
<td>Zn</td>
<td>1 kg</td>
</tr>
<tr>
<td>Boron</td>
<td>1 kg</td>
</tr>
</tbody>
</table>


The physical delivery of 1.5 tons of inputs per ha provides a formidable, and in many cases an insurmountable, constraint to the widespread use of this technology. Lime is not widely available in many of the humid tropical forest areas, and long transport hauls for this product make the technology economically unattractive, and physically impossible to execute within anticipated levels of infrastructural development. As the sole basis for maintaining fertility this is unlikely to prove a practicable technology for the great majority of small scale farmers in the zone; and

(d) agroforestry. Farmers in the forest zone appreciate the role of trees in restoring fertility during fallow periods and know of species which are particularly effective in this respect. Shortening fallow periods which involve more frequent pollarding of the trees lead to the weakening of this system. Work at IITA has demonstrated that the replacement of traditional species with trees which are both leguminous and tolerant of frequent pollarding can help to slow down soil degradation. On non-acid soils the focus of attention has been on Leucaena leucocephala, but on more acid soils of the humid zone this is not a suitable plant and trials are in hand with a number of species including Cassia siamea, Flemingia congesta and Acioa barterii. There are hopeful early indications that degradation can be reduced by the use of
large numbers of trees in hedges which alternate with crops. Trials are now being carried out on farmers' fields. These show that the system requires a 50% increase in labour input over traditional methods. 1/ The timing of the labour demand is also critical. If the hedges overgrow then crop yields are seriously depressed. This is a hopeful technology but it is still in the development phase in the humid zone and further technical and economic analysis is required before it can provide a clearly defined extension message.

As farmers face the changing situation imposed by increasing population pressure they are adapting and adopting from all of the above technologies. The extension of the organically based compound farm, some fallow, some fertilizer and the preservation of trees in the crop farm are all part of their strategy. These are not enough to offset yield decline when population pressure becomes severe. Work in Eastern Nigeria by Lagemann 2/ records the decline in yields resulting from shortened fallows induced by population growth. In three villages selected for uniformity of soil type and social organisation the average yields of cassava were 10.8, 3.8 and 2.0 tons per ha relating to average fallow periods of 7, 4 and 2 years.

Within the cultivated field itself there is also scope for slowing the process of degradation and leaching by providing good ground cover early in the rainy season. Traditionally farmers have achieved this by planting a range of different crops in their fields. Research has been carried out to provide more cover through the use of no-till methods (based on herbicide) and leguminous cover crops. This work has yet to produce financially attractive practical extension messages for small scale farmers. In the meantime it is important that extension staff do not encourage farmers into single crop farming in the name of modernisation.

Bank Funded Initiatives in the Zone

For this zone five Bank-funded projects, which include the food crops covered by this study, have been selected for analysis. These are:

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Nigeria: Multi-state Agricultural Development Project I
Liberia: Bong County Agricultural Development Project II
Liberia: Smallholder Rice Seed Project
Sierra Leone: Eastern Integrated Agricultural Development Project III
Cote d'Ivoire: Center-West Agricultural Development Project

The problems of soil fertility receive varying attention in the project documents, but only in the Nigerian project is it considered a major constraint on production and consequently on project impact. Proposals to offset fertility decline included:

(a) the use of fertilizer in small quantities. This was seen as helping to temporarily increase yields rather than offset long-term decline. The viability of this proposal is heavily dependent on other soil factors and pricing policies. In the Liberia rice seed project an attempt was made to extend the number of years of rice cultivation between fallows but the cost of fertilizer far exceeded the value of incremental rice produced. On the other hand fertilizer on cassava in Nigeria offers attractive returns;

(b) the switch from upland to swamp rice. In Liberia it became clear that the returns to labour for swamp rice were often lower than for upland rice in land abundant areas and the switch did not take place;

(c) encouraging research to investigate solutions to the problem; and

(d) focusing extension attention on compound farms in which fertility is being maintained with household refuse.

The shortage of concrete proposals to offset fertility decline reflects the absence of viable, proven technology for long-term soil fertility maintenance under annual cropping in the humid forest zone in areas where adequate fallowing is no longer possible.

Crop Production

In considering the technology available for improving the productivity of individual annual food crops in this zone the underlying constraint of soil fertility maintenance has to be borne in mind in areas where land availability is seriously curtailing fallows. IITA sees "soil productivity as the principal resource concern of the humid tropics of Africa
because it is the major limiting factor'. Lagemann's work shows that when land availability is limited then 60% of yield variation between plots can be attributed to fallow length (p. 68). Given the great range in population pressure in the zone it is particularly important to tailor extension messages to actual situations. Attempts to introduce labour intensive methods of fertility maintenance in areas of land abundance are likely to fail. Equally a focus on short-term crop specific messages in a situation where soil deterioration is the main constraint is likely to have limited success. The following sections on individual crops should be considered against this background of soil fertility issues.

The major crops of the humid tropics of Africa in order of importance are cassava, yam, maize and rice. These will be considered in the following sections.

**Cassava**

This crop occupies two distinct places in the farming system and its management and the applicability of alternative technology need to be assessed in the light of this situation. These are:

(a) cassava is a major part of the diet and a central crop in the farming system. The crop is planted at an early stage in the farming cycle, is weeded and given priority in labour allocation; and

(b) cassava is peripheral in the diet and is seen as an inferior famine reserve food. The crop is planted on worn out land at the end of the rotation because of its ability to extract phosphate from poor soils and tolerate acid conditions. It is often not weeded because the land is entering its fallow phase and the weeds contribute to the plant succession which is needed for restoration of fertility. The crop takes a low priority in the allocation of labour.

The possibilities for raising productivity will be reviewed for both of these situations. The analysis will consider the choice of planting materials, field practices and the use of inputs.

**Planting Material**

Cassava yields in Africa are increasingly constrained by two major diseases, mosaic (CMD) and bacterial blight (CBB) and two newly introduced pests, green mite (CGM) and mealybug (CMB). The spread of these is not yet universal but covers much of the main growing areas. The International Institute for Tropical Agriculture (IITA) has therefore concentrated its breeding efforts on producing material resistant or tolerant to these. These factors have at times taken precedence over other features which are of concern to farmers, such as time of maturity, suitability for intercropping, the period for which the roots will remain edible once they have matured and their quality for preparing local traditional dishes. The IITA releases have

multiple branches from low down on the plant and are leafy. These are features of the genetic material from which the resistance to CMD was drawn. It is not an ideal architecture physiologically or from the farmers' point of view in certain intercropping situations. The roots become fibrous soon after maturity and do not store well in the soil. The plants have good resistance to CMD and CBB, some tolerance to CGM but none to CMB. In areas where CMD and CBB are major problems these varieties will outyield local non-tolerant material and are gaining in popularity. Elsewhere some of their disadvantages limit their attraction to farmers. Research is continuing at a number of centres to overcome these limitations.

In summary there are new releases of planting material available from research stations which may offer farmers improved yields in situations in which disease is a major constraint and where short-term cassavas are needed. Those based on IITA varieties are not suited to farmers using cassava as an "in soil insurance" crop. There is every reason to expect that there will be further improvements resulting from cassava breeding programs over the next ten years. In Nigeria, the second largest cassava producer in Africa, it is estimated that up to 10 per cent of the cassava area has been switched to IITA varieties over the past ten years. On the basis of further improvements in the breeding program it is expected that this figure could increase to 30 per cent over the next decade. It is not possible to generalise as to the impact of the adoption of the new releases on yield as this is so heavily dependent upon levels of soil fertility, disease pressure and the relative maturity periods of new and existing material. There is still considerable scope for moving existing local cultivars with desirable features from one area to another which they have not yet reached. This is happening all the time within African rural communities but is an aspect of technology transfer which deserves more detailed attention on a pan-territorial basis by extension services. The fact that it has not always done so is in part a reflection of the low esteem with which many agricultural staff view cassava despite its dominant role in the cropping pattern of this zone.

Apart from the choice of variety there are three other features of cassava planting material which can influence yields. These are the health and vigour of the cuttings, their degree of maturity and their length.

The selection of undamaged planting material from plants which are visually free of disease can have a substantial impact on yields. The difference in yield between healthy and damaged and diseased cuttings will vary widely between sites and generalised figures are meaningless. There is good evidence, however, that the use of fresh clean material provides perceptible increases in yield at little extra cost, and offers a sound and widely applicable extension message.

The degree of maturity of the cuttings used for planting has an impact on the time of tuberisation and a modest impact on yield. Cuttings in which the diameter of the pith is 50 per cent of the diameter of the stem are mature enough to make good planting material. The effect of selecting mature material will naturally be greater on an intensive, short term crop than one which is left in the ground for several years under fallow conditions.
Large numbers of experiments have been carried out to determine the effect of length of cutting on yield. Lengths from 10 cm to 80 cm have been used with wide variations in response depending on soil and climatic conditions. It appears that there is unlikely to be much difference in yield from using cuttings of between 25 and 45 cm. Longer stakes (up to 80 cm) give quicker ground cover, but do not provide higher yields. Farmers commonly use cuttings within these limits and it is unlikely that there are many situations in which changing the length of cutting currently being used will have a significant impact on yield.

Field Practices

The main field practices which can affect yields are planting methods, plant population, time of planting and weeding.

As with planting length there have been many experiments with planting methods. A number of these have found no significant difference between horizontal, inclined or vertical planting. In this wet zone vertical planting may have slight advantages, but it is unlikely that farmers will achieve any perceptible increase in yield by changing from one method to another.

Optimum planting density is highly dependent on variety, soil fertility and the ultimate use for which the root is required. Short varieties will give higher yields at higher populations (7-10,000 plants per ha) whereas tall, branched varieties will give their optimum yield at half that density. On poor soils increasing plant density will often result in increased yields, which is why many African farmers plant at densities well above the recommendations of research stations which are derived from work on more fertile soils. The literature offers widely conflicting advice on populations which reflects the range of both the morphological features of cassava and the environmental conditions under which it is grown. Optimum populations vary between 2,000 and 10,000 per ha and need to be assessed in the light of individual conditions. Cassava intended as a fallow crop should normally be planted at wider spacing to ensure a strong growth of colonising wild plants to fulfill their function of restoring fertility.

Time of planting certainly has an impact on yields, particularly when the crop is not part of a longer term fallow. The introduction of CMB and CGM has increased the yield advantage of planting early in the rains in order to produce well developed plants before they are attacked by the pests, which flourish in the dry season. Cassava is seldom planted in pure stand, however, and planting dates are often governed by the needs of associated crops. Any recommendation on planting dates must be set in the context of the needs of the whole crop mixture and not only the cassava. Because the crop is semi-perennial it offers farmers the opportunity to flatten out labour demand peaks. In consequence more time sensitive crops (e.g. yams and maize) are given priority early in the season and cassava is fitted in when there is labour available. The threat of CMB and CGM may change that situation in some ecological areas so that the date of planting of cassava
becomes equally sensitive as that of other crops which compete with it for labour. Under such circumstances it may be necessary to restudy the farming pattern and see how it can be changed to allow for earlier planting of cassava.

Weeding can have a substantial impact on yields and the literature quotes reductions of 50% resulting from weed competition. Where the crop is the component of a fallow the yield of cassava is not a dominant consideration and clean weeding could be detrimental to soil restorative processes. In mixed crop situations in which cassava is late planted in to the system the main competition is likely to come from companion crops rather than weeds. Where cassava is the dominant crop then two weedings in the first three months of growth would be expected to provide measurable yield increases and a worthwhile return to labour. Once again quantitative generalisations are meaningless over so wide a range of soil conditions.

The Use of Inputs

None of the main purchased inputs, insecticides, herbicides and fertilizer are used in significant quantities on cassava in this zone. The control of major pests and diseases is being addressed through breeding and biological methods. Herbicides are available which are suitable for cassava and a mixture of Diuron and Alachlor provide good weed control. Under current farming systems and price regimes they do not offer an attractive alternative to hand weeding. Only in Nigeria, where fertilizer use has been encouraged by heavy government subsidy, do farmers use some fertilizer on cassava. Cassava does extract large quantities of nutrients from the soil however and in areas in which it is either the dominant crop, or one which plays an important role as a staple food, increasing attention may have to be given to its fertilisation as opportunities for fallowing are reduced.

Potassium (K) is the major nutrient extracted by cassava from the soil. Per ton of dry matter harvested it removes three times as much K as maize and four times as much as rice. Falling cassava yields can often be attributed to declining levels of K in the soil and this should be the focus of attention in any program intended to raise yields in conditions where there is inadequate fallowing. Application of nitrogenous (N) fertilizer in the absence of adequate K is unlikely to have a positive impact, but on poor sandy soils there have been linear responses to moderate applications of N in a balanced fertilizer mix. Cassava normally has a mycorrhizal association which makes it extremely effective at taking up phosphorus (P) from the soil and it has a critical soil-P level half of that of maize. Under conditions of moderate soil fertility there is likely to be little response to P, but as fertility levels fall there can be increasing responses to this element also. Unfortunately the little work which has been carried out on the fertilisation of cassava in the wet tropical zone of Africa has been on research stations where soil nutrient levels are often much higher than on farmers' fields and provide little guidance as to the likely impact of added nutrients on the degraded soils on which the crop is often grown. The limited work available in Nigeria has shown that farmers can obtain about 20 kg of cassava roots per kg of nutrient contained in a compound of 12 N 12 P 17 K. In any situation in which it appears that a serious effort is justified to prevent yield decline through the use of fertilizer on cassava
it will be necessary to establish what level of K is required to offset deficiencies of that element, so as to limit any waste of N and P and so ensure the maximum return to the fertilizer being used.

Summary on Cassava Technology

Because cassava is still a crop of last resort for a number of farmers in this zone it has often not been given priority in the allocation of either farmer, research or extension resources. In areas with high levels of population pressure cassava has now become the dominant food crop, and therefore is being given higher priority by farmers. This will happen over increasing areas. Under these circumstances it is possible to achieve yield increases through much more careful selection of planting material. As pressure on land increases, the returns to fertilizer, especially potash, can become attractive. Hopefully the breeding programs of this zone will soon come forward with disease resistant material which will also be widely acceptable to farmers and provide a significant opportunity to increase yields without increasing labour demands or input costs.

Experience of Bank Funded Projects with Cassava in the Humid Tropics Zone

Despite this crop's major role in the food economy of this zone it has not been the focus of attention in many Bank-funded projects, which may reflect the crop's reputation as being residual, even where it is actually the dominant annual crop. Amongst the five projects in this zone selected for this study three included a cassava component.

The Sierra Leone Eastern Integrated Development Project III recommended that farmers should be encouraged to plant cassava in lines and not in a random manner within a portion of their rice fields. No yield increase was estimated to result from this change. The Nigeria Multi-State Agricultural Development Project I placed considerable emphasis on cassava. Increased production of the crop was expected to derive from two sources:

(a) the use of improved planting material. A switch from existing local cultivars to IITA derived material was expected to result in an average yield increase of 38 kg of fresh roots per bundle of new cuttings used, which is equivalent to 1.5 tons per ha; and

(b) the use of fertilizer on cassava. It was assumed that 1 kg of nutrients in a compound of 12-12-17 would result in the production of 20 kg of extra fresh root. At the time of appraisal this offered farmers a B:C ratio on fertilizer and incremental labour of 2.12:1 at the unsubsidised price and 3.71:1 at the actual price then prevailing. Since the time of appraisal the exchange rate has changed from $1 = N 0.89 to $1 = N 5. The result has been a sharp increase in the naira cost of fertilizer from N 289 to N 1,200 per ton. At the same time the government has banned the import of wheat which has raised the price of cassava which is the competing convenience food. As a result of these changes the B:C ratio
at the unsubsidized fertilizer price is now 1.6:1, but as a result of an increase in government subsidy the actual B:C ratio has risen to 6.9:1.

Neither of these innovations call for any significant increase in labour input but their validity has been changed by economic factors. The experience in this project could provide useful guidelines for other parts of the humid forest belt, particularly in situations in which cassava is a major food crop for local urban markets.

In the Liberia Bong County project, increased production was expected to derive from a change from local cultivars to material coming from IITA. Unfortunately this component was not implemented and so its possible impact could not be judged.

Yams

Within the humid tropical zone yams are the second most important source of calories. Because of strong consumer preference for the crop the price of a thousand calories from yams is four to five times higher than that for maize and cassava. In consequence returns to labour are high and the crop is given priority in the allocation of resources. The possibilities for raising production through the application of available, applicable technologies will be considered in relation to planting material, field practices, staking and the use of inputs.

Planting Material

The main yams grown in this zone are white yams, yellow yams and water yams, with white yam being dominant. The first two are indigenous to Africa the last was imported from Asia. Because the main yam species are indigenous, and because West Africa grows 96% of the world's yam production, the material in the world collection is almost entirely derived from West Africa. Technology was developed in Ghana to grow yams from true seed. This was refined by IITA to produce up to 10,000 genetically diverse seedlings annually for clonal selection. To date no improved material has been released from this program and IITA, after some fifteen years of experience, has stated that rapid improvement of yams through breeding is extremely difficult because of the reproductive complexity of the genus Dioscorea. 4/

At the same time there has been an introduction of a yam from the Caribbean into the Cote d'Ivoire called Florido which offers farmers substantial yield increases over existing cultivars. This belongs to the species Dioscorea alata, the water yam, which is the second choice of consumers and fetches a lower price than D. rotundata, the white yam. Farmers who were already growing water yams have readily accepted Florido and it is spreading to neighbouring countries. Unless a method of processing

can be found which improves on the eating quality of water yam it is likely to remain a low priced minor contributor to the total market. Where farmers already use alata yams then Florido offers a real opportunity to achieve yield increases without extra labour or inputs.

Apart from breeding, most attention has been focused upon the fundamental problem with yam production which is that up to a quarter of the crop has to be used for planting material. Work at the Nigerian National Root Crop Research Institute has refined traditional methods of producing yam setts using only small pieces of tuber. With skill, and the necessary inputs, this can increase the multiplication ratio by a factor of ten. This could release more yam production for direct consumption, but an analysis of the system by IITA has shown that it does not reduce the cost of yam setts because of the resources of land, labour and inputs which it involves. It is likely that this technology will become popular with farmers who specialise in sett production and to a lesser extent with producers of ware yams. Research is continuing to improve on this technology so as to increase its efficiency, reduce costs and expand its applicability.

The "mini-sett" technique described above is already in use. Some work is now being carried out on the use of in vitro methods of rapid clonal propagation from tissue culture to produce "mini-tubers". Under such a system hundreds of thousands of mini-tubers can be produced in one year from a single 100 g. yam sett. This technology is still not near to field testing but it has within it the potential to greatly increase the efficiency of yam production.

Field Practices

Field practices are largely governed by the type of yam which is currently in demand. There is a preference for large tubers which require wide spacing and a deep, friable soil in which the tuber can develop. This reduces the yield per unit area of land and calls for high labour input for making mounds or digging pits to ensure good shape. Recommendations on spacing and cultural methods have to be geared to this reality. Wider spacing also increases the yield per sett, and as these represent 30% of the cost of production this is a major factor to be considered in any spacing recommendation. Yields per ha can be increased in most situations by raising plant populations but this may involve substantial financial losses through a decline in tuber quality and an increase in the ratio of planting material to ware yams.

As people in the humid zone have to make increasing use of yams imported from drier areas, which have smaller tubers, there may be a change in consumer demand and a decline in the premium paid for large tubers. A reduction in the cost of setts could combine with such a change to make higher plant populations and higher yields per ha more attractive. Extreme population pressure which greatly increases the value of land could have a similar impact. In the meanwhile plant populations and methods of land preparation need to be reviewed in the light of returns to the enterprise and not just in terms of yields per ha.
Yams are intolerant of competition from other plants which can shade them, and weeding has a profound affect on yields, with poor weed control resulting in a 50% reduction in yields. Farmers are well aware of this and give priority to yam weeding, but may face labour constraints at a time when the weather is usually unsuitable for weeding because of daily rain. Work in Nigeria has shown that by trebling the population of the intercropped, creeping melons usually planted by farmers, weed growth can be greatly reduced without the melons having any adverse impact on the yams. This technology deserves wider testing as being a means of reducing labour input at minimal incremental cost.

Staking

In the humid tropical zone with its low levels of insolation the yield of white yams is heavily dependent upon staking both to increase photosynthetic activity and reduce infection with anthracnose. Yields of unstaked yams are less than fifty per cent of staked yams, and up to a limit of about 4 m. the height of the stake determines the yield of the yam if other growing conditions are favorable. It is therefore quite simple, technically, to greatly increase yam yields by improving on the quality of staking. At present there is a serious shortage of conventional staking material in many areas so that there is not a practicable technology to offer farmers. Research work has failed so far to produce a white yam which does not require staking and the focus of attention by extension staff should be on alternative methods of support (e.g. string instead of stakes) and on producing staking material within the farming system through agro-forestry.

The Use of Inputs

There has been a limited use of purchased inputs on yams, but Nigerian farmers do make use of both insecticides and fertilizer. The insecticide is for the control of beetles which eat the setts after planting. Aldrin has proved highly effective in this respect and is popular. Unfortunately it has a high level of mammalian toxicity and research staff will need to identify less hazardous alternatives as Aldrin is withdrawn from sale.

The response of yams to fertilizer is far from uniform but many field trials over the past forty years have shown good responses to a compound made up of 12 N - 12 P - 17 K. In Nigeria it appears that yams will give an average of 14 kg of increased tuber yield in response to 1 kg of nutrients from such a compound. Farmers have been quite resistant to the use of fertilizer in some areas despite its attractive returns as they state that it produces a more watery product with poor keeping qualities. Research has not been able to duplicate this finding, and other farmers make no such complaints so that it may be linked to particular soil and climatic combinations.

Experience of Bank Funded Projects with Yams in the Humid Tropics Zone

Only two of the projects included in this study have components intended to improve on yam production. In the Cote d'Ivoire Centre West
Project a small component, covering 300 ha by year 5 was expected to raise yam yields from 8 to 10 tons per ha. The technology to be adopted for this was:

(a) a better selection of yam setts. Unfortunately no indication is given as to the constraints facing farmers with regard to the availability of yam setts, nor as to the comparative advantage of reducing the area planted rather than using sub-standard setts in a situation where planting material is the main constraint on the area planted;

(b) the use of 15 kg of Aldrin per ha at planting; and

(c) early weeding. The constraints currently preventing farmers from early weeding are perhaps underestimated. It is noticeable that one of the means of raising rainfed rice, maize and groundnut yields in the same area is through early weeding. Under these circumstances more attention should have been given to the order of priority as to which crop will suffer least from the late weeding which is inevitable in a situation in which a number of crops are planted at the same time, and weeding days are limited by daily rains.

Under the Nigeria MSADP I project it was proposed that action be taken to further popularise and refine the technique for mini-sett production. No benefits were attributed to this exploratory exercise. It was also proposed to initiate a change in insecticidal treatment away from Aldrin. The benefits to this would be to human health. The expanded use of fertilizer was the component expected to provide the quickest return. At unsubsidised prices at the time of appraisal the use of 100 kg of 12-12-17 fertilizer at the recommended rate provided a B:C ratio of 9:1 and at the subsidised rate it was 12:1.

The change in the unsubsidised price of fertilizer resulting from devaluation now gives a B:C ratio of 4.2:1 but with an increase in the level of fertilizer subsidy the actual B:C ratio to the farmer is now 14:1. It appears that the technology put forward in the SAR remains attractive at current prices because of the high premium that consumers place on yam.

Upland Rice

There are an estimated 1.070 million hectares of rice in this zone. Of this the majority (60%) is grown on uplands, the remainder is grown in lowlands with widely varying degrees of water control. Upland rice is grown by slash and burn methods in the forest zone. Trees and brush are felled and burned and this process provides a comparatively clean seed bed and the nutrients necessary for the production of one, and under better soil conditions sometimes two crops. Typically these soils are strongly leached and extremely acid and aluminum toxicity is a substantial constraint. Cultivation is minimal and the adapted cultivars have a strong rooting system which is able to establish well under these circumstances. Because the burning destroys most weed seeds there is little necessity for weeding.
Yields are largely determined by the length of fallow between two crops, and to a lesser degree by the variety being used.

With increasing population pressure fallow length is being reduced in some areas and this is leading to falling yields, and presenting severe challenges to agriculturalists as to how to sustain production by alternative methods. Attempts were made in Liberia both by a Chinese rice project and an IFAD funded project to grow upland rice without fallowing. Both projects managed to continue rice production for four years, but by year three the cost of purchased inputs alone (without labour) was greater than the value of rice harvested. This resulted not only from increasing soil acidity but from ever more serious weed problems.

This is a situation in which the timing of the introduction of innovations is critical. In areas in which fallowing is still a viable means of maintaining fertility and suppressing noxious weeds it is unlikely that it will be possible to provide farmers with a more attractive alternative. Under such circumstances farmers can be introduced to improved local selections (such as LAC 23) if they are not already using them, but yield gains from these are modest under the traditional system. They may be able to benefit from a modification in plant populations. The tall, leafy varieties which survive the adverse soil conditions and the challenge of blast which typify this zone, are poorly responsive to N fertilizers, and any recommendation to use them would usually depend on substantial local distortions in input or output prices away from international levels.

In areas where shifting cultivation is no longer possible and where fallows have been drastically shortened farmers face two options. These are:

(a) intensify upland rice production using purchased inputs and greatly increased labour for cultivation and weeding. This will involve lower returns to labour than traditional methods and greater risks; and

(b) move out of upland rice into lowland production, if suitable areas are available. This also involves a drop in output per unit of labour as compared to traditional systems when land is abundant.

As both of these options are likely to involve falling returns to labour (particularly adult male labour) by comparison with extensive systems with adequate fallow they will only be taken up under pressure. The first has not been widely adopted and there is limited knowledge available as to its viability over a range of conditions. Levels of fertilizer use, land management practices and varietal selection will be heavily dependent upon local circumstances, and broad guidelines on technology are of little use. The second option will be covered in the section on lowland rice.
Experience of Bank Funded Projects with Upland Rice
in the Humid Tropics Zone

Of the five projects covered in this review only the Nigerian one
did not have a significant component intended to increase upland rice yields.

In all the other four it was expected that making improved seed
available to farmers would lead to crop increases. In the Liberian case this
was the variety LAC 23. This is a local selection released over twenty years
ago. The Smallholder Rice Seed Project anticipated that the use of LAC 23
would result in a 200 kg per ha increase in yield. The Second Bong ADP
expected the same variety to give an extra 300 kg per ha. In the event
farmers did not obtain yield increases sufficient to encourage them to buy
the seed that was produced, and it has had to be disposed of with a large
subsidy under seed exchange arrangements. The main reason for this is that
farmers in the area had been exposed to LAC 23 for many years and their
existing fields were largely planted to this material. This experience again
highlights the need for sound information and appropriate timing in the
introduction of technical change. In neighbouring Guinea where LAC 23 had
not been available in the past its introduction produced observable yield
increases on farmers fields.

In the Sierra Leone Project, LAC 23 provided the basic innovation
under the project and the switch to this variety was expected to result in
a 333 kg per ha increase in yield. A bilaterally funded seed project
produced seed for this component but, as in Liberia, the yield increment
obtained by farmers was inadequate to encourage seed purchase at anything but
heavily subsidised prices.

The experience of these projects is that under traditional systems
of management the improved seed that is available may provide farmers with
some yield increase, but that it is not enough to stimulate a demand for seed
at anything approaching the true cost of production and distribution.

Two of the projects recommended the use of fertilizer to raise
yields. In the Cote d'Ivoire it was reckoned that 50 kg of urea per ha would
provide an increase of 200 kg of paddy. This assumes the 1 kg N gives 8.7
kg of incremental paddy. In Liberia it was recommended that between 20 and
30 kg of N be applied per ha when farmers had to fallow for less than 5
years. No response figures were given but it was expected that this dressing
would help to partially offset yield decline. These projects highlight the
problems of intensifying the production of a traditional farming system under
difficult soil conditions in which plants have been selected for particular
features which do not necessarily lend themselves to a different set of
production conditions. Under these circumstances project interventions which
are expected to work within the existing system are likely to have only a
modest impact, while alternative systems are only at an early stage of
experimentation.
Lowland Rice

Scattered across this zone are areas of swamp and wetland in which rice is grown under a wide range of conditions with regard to water availability and control. These vary from brackish mangrove swamps, deep flooded floating rices, bottomlands with no control over the water, to fully irrigated paddies. This paper cannot cover this range and will focus on a few salient points at which viable technical innovations may be available. These will be considered under headings of planting material, water control, agronomic practices and the use of inputs.

It is in the move from upland to lowland farming and from the opportunistic use of flooding to fully controlled irrigation that the timing of the introduction of innovations is of particular importance. These moves often require major incremental labour inputs which will only be forthcoming when there is sufficient external pressure to force people into them. Misjudging the degree of that pressure can make the difference between acceptance and rejection of a technical change.

Planting Material

The green revolution in rice growing in Asia was built around good control of water through irrigation, good control of pests and diseases through the use of chemicals and good control over the availability of nutrients thought the heavy use of fertilizers. There are small areas in the humid tropical zone in which good water control has been achieved and the sophisticated infrastructure has been developed to ensure the timely availability of the appropriate inputs. In such areas comparable material to that which has been so successful in Asia can be used, although direct transfers are limited by the seriousness of Rice Yellow Mottle Virus which does not occur outside Africa.

In most areas these conditions do not apply and varieties have to be much more tolerant of varying water regimens, iron toxicity, late transplanting because of erratic rainfall and a range of pests and diseases for which chemical methods of control are not locally available. Rice research has been carried out for 60 years in West and Central Africa so that there are a number of releases available covering a range of ecologies. In selecting one of these to improve on farmers' yields it is critical to assess whether the farmer also has the resources (not just instructions) to improve on water control, weed control and plant nutrition. If he has not, then it may prove a disadvantage to change the variety, unless it has similar degrees of tolerance to low levels of management and difficult environmental conditions (e.g. iron toxicity) as the existing material. Conversely where farmers are able to improve on their management they may be able to make still more gains through a complementary change of variety. Under these conditions the inter-relationship between water and weed management, nutrition and varietal response are so interwoven that broad generalisations about the yield gains to be obtained from adopting a new variety are of little significance.
Water Control

Good water control is strongly linked with making a significant impact on lowland rice yields. It is pertinent to note that the green revolution was brought about on farms on many of which the installation of water control and its methodology had been developed over hundreds of years. Often there have been steady refinements of the system by successive generations. In the zone under consideration this is not the case. Where rice is grown under deep riverine conditions or in mangrove swamps there is often no simple method of improving on water control. Under inland swamp conditions it is much more possible to achieve considerable improvement. The technology to achieve this will vary from one situation to another but it is well within the scope of a competent land use officer to design suitable structures which will be physically efficient at controlling flooding and managing water depth in the paddies. Technical knowledge is not the only determinant of viability for farmers in these areas. The following factors are of major importance in considering the practicability of water control in swamps:

(a) in most cases a number of farmers will have to cooperate in order to bring about effective water control and an individual will make little progress on his or her own;

(b) only hand tools are available with which to carry out drainage works and levelling. Even under quite favourable conditions initial development of a drained swamp requires some 300 man days per ha. Any significant levelling will require additional labour, and annual maintenance of ditches and bunds requires a further 30 to 40 days. Much of this heavy work is carried out by men; and

(c) many people are averse to working long hours in swamps because of the leeches and the dangers of contacting bilharzia.

In assessing the viability of swamp development it is particularly important to estimate the comparative returns to incremental labour (and particularly male labour which is critical for bush clearing on the upland, and swamp development on the lowland) invested in extending the area under rainfed rice or developing improved water control in the lowlands. In land plentiful areas the upland will often give higher returns. Only under land pressure is water control likely to provide a technology which is financially attractive and therefore acceptable to farmers.

Agronomic Practices

There are well researched technical innovations available, with good supporting data, which can bring about substantial increases in yield from lowland rice. Not all of these are within the farmer's reach however, and the development of advice must include methods of overcoming the constraints which prevent farmers from carrying out practices which they know would enhance their yields. It is therefore quite simple to detail actions which could bring about yield increases in lowland rice, but their
practicality as technical messages can only be judged on the basis of individual circumstances. A good example of this was provided by the numerous Taiwanese missions in West Africa which demonstrated that high and consistent yields could be obtained with the rigid application of strict standards of agronomy. Farmers were thoroughly trained in the methods to be used, but the high yields have not survived the withdrawal of the Taiwanese. This experience deserves further study to provide lessons for future initiatives.

Among the most important factors which deserve review in assessing the scope for improving yields are:

(a) reducing overcrowding in nurseries. This is a common fault and is within the scope of most farmers to rectify;

(b) transplanting when seedlings are at their optimum point for this change. Many farmers have no control of when they can transplant because of the wide variation in rainfall patterns between seasons. Where this is the case it is essential that farmers do not switch to short high yielding varieties which are extremely sensitive to delayed transplanting;

(c) spacing and depth of transplanting of seedlings. There is considerable scope for achieving yield increases through improved transplanting. Because the work is laborious and tedious it is often given to paid labourers or to children. Small demonstrations of the impact of careful planting are well worthwhile, to offer farmers evidence of the potential returns to much closer supervision of this activity;

(d) weeding. Poor weed control can reduce yields by 50%. Farmers are usually well aware of this fact but do not see a ready way to deal with the problem. Herbicide use is in its infancy in most of this zone, and too much has often been expected from a single application. There are seldom easy answers to this problem but technical staff should review the potential for better water control, the use of herbicides and possibly a reduction in farm size as possible strategies to assist farmers with this constraint.

The Use of Inputs

Fertilizer is the most common input used on lowland rice in this zone, and N is the most widely used element. Under flooded conditions at least 50% of the N which is applied is lost. Research continues as to how to minimise this loss. Deep placement is the most hopeful method, but existing recommendations for its use are labour intensive and have not gained acceptance by farmers. Response to N under lowland conditions varies greatly. The main determinants are:

(a) variety. Traditional varieties show little response to fertilizer as compared with modern material;
(b) the degree of water control. In areas subject to periodic drying and water stress high levels of N will either be wasted or depress yields; and

(c) weed control. Additional nutrients stimulate weed growth and if this cannot be controlled then the fertilizer will have a reduced impact on rice yields.

Response ratios vary widely under different levels of management but assumptions of between 10 and 20 kg of paddy per kg of N are realistic. Under some conditions both P and K may be required, but deficiencies of these elements are less common in lowland as compared to upland conditions.

It is possible to meet part of the N needs of rice through the use of azolla or sesbania both of which are plants that are capable of fixing atmospheric nitrogen. Their use is labour intensive, and in China, where azolla used to be a common feature of rice systems, it has largely been replaced by urea. Experimental work is being carried out on these plants in West Africa but the viability of the technology will be heavily dependent upon labour availability at critical periods, and the comparative returns to labour and purchased fertilizer which will vary widely by location.

Herbicides are another purchased input which has been used by lowland rice growers in this zone. Unfortunately farmers have often thought of herbicides as an easy, 'quick fix' method of dealing with weeds. Under flooded conditions this is not so, and several different products, applied at different times in the growth cycle, may be required to achieve effective control. Type of weed, type of soil, degree of water control as well as the comparative costs of different herbicides are all factors which need to be considered in selecting an appropriate weed control program. Good technical information on the specific conditions in the area combined with a strong extension service to demonstrate the accurate use of the chemicals are essential prerequisites for successful herbicide use. Without them farmers are likely to lose money through inappropriate use of expensive inputs. Technical viability in this case does not depend so much on research on weed control, as on the level of available technical support, timely and dependable supply services and comparative prices of labour and inputs which are often determined by the levels of distortion in the exchange rate.

Insect pests can cause serious yield losses to lowland rice. Stem borers are a particular problem against which chemical control in the field has had little success. The thrust of research in the zone is to develop genetic resistance to pests rather than rely on insecticides, and there is little validated information available on viable chemical methods of control.

Experience of Bank Funded Projects with Lowland Rice in the Humid Tropics Zone

All of the projects being considered in this zone included components to encourage increased production from lowland rice.

Three projects were expected to stimulate the development of new swamp areas, but with differing degrees of intervention. These were:
(a) Sierra Leone, technical advice on pegging out drainage lines only;

(b) Liberia Bong II, technical advice plus loans for farmers to hire labour for land development; and

(c) Cote d'Ivoire, direct project involvement in land development.

The areas involved in these projects were modest, ranging from 350 ha for Liberia in a project area with 22,000 rural households to 980 ha in Cote d'Ivoire in a project area with 80,000 rural households. This provides some indication of the fairly low levels of farmer interest in carrying out swamp development so long as upland farming is possible. The first Bong project had a target of 2,000 ha of swamp development and achieved 335 ha.

The same three projects planned to increase yields through a series of changed husbandry practices including:

(a) better nursery management;

(b) better standards of transplanting;

(c) better water control; and

(d) better weeding.

All of these called for considerable additional labour, and this may account for the fact that farmers did not follow all the recommendations and overall yields were consequently below the appraisal expectations.

Two of the projects were involved in promoting fertilizer use. On the fourth (in Cote d'Ivoire) farmers were already being issued with free fertilizer for use on their rice. Both propose similar levels of fertilizer use, but there is no indication as to the benefits that are expected to derive from the fertilizer itself and yield increases are estimated on the basis of a combination of factors.

All the projects proposed the encouragement of the adoption of improved varieties. In only one project was there an attempt to quantify the benefit to be derived from switching varieties under existing lowland conditions. This was in Nigeria where amongst established rice farmers it was estimated that a change to newly released material would result in an increase of 2.5 kg of paddy for each kg of seed purchased and a further 1.65 kg of incremental production per kg of kept seed in the second year of its use assuming no other change in management. This translates into 150 kg per ha in the first year and 100 in the second. This appears a modest estimate which should be achieved, but may not provide sufficient impetus for farmers to purchase new seed at commercial prices, when such seed usually cost 2.5 times the price of the grain in the market.
Maize

Although there is a considerable area reported to be planted to maize in the humid forest zone much of the crop is planted in mixtures with other crops and harvested green for immediate consumption. Low levels of insolation reduce yield potential and high humidity makes harvesting and storage difficult. In addition many of the soils of this zone are too acid for optimum maize production and there is high disease and insect pressure, including downy mildew and a range of lepidopterous stem borers.

For the maize grown as a minor crop in other mixtures, as a source of green cobs, there is not at present much improved, appropriate technology available. Increasing plant populations can lead to the reduction in the production of other more important crops, such as yams, and at the same time may result in local over-production of perishable green maize, the price of which slumps dramatically during the main harvest season.

In some areas farmers attempt to grow a "second season" crop, planted at the height of the rains, but maturing under drier conditions. This crop suffers severe attacks from Eldania and Sesamia as well as from downy mildew, all of which limit yields. Insecticidal treatment has not proved a viable proposition under these circumstances and research efforts are being focussed on producing resistant material which could provide an appropriate technical improvement in the future. The same applies to the fungally induced ear rots which are a serious problem in this zone. When research is able to add resistance to these to that which now exists for streak virus, lowland rust and blight it may become possible to give maize a more important place in the agriculture of this zone to which it is now only marginally suited.

No component for maize in this zone was included in any of the five Bank funded projects covered by this review.
2. THE SUB-HUMID ZONE OF WEST AFRICA

Background

This zone comprises a range of woodland and wooded savanna types with a rainfall of between 1,000 and 1,400 mm per year. It is more extensive than the forest zone but much less thickly populated. In several West African countries it represents the land resource on which least pressure has been placed. About 40 million people live in this zone which covers 1.1 million square km.

The positive assets of this zone as compared with the forest zone are higher levels of insolation which result in a high photosynthetic potential and soils which are less leached and fragile.

The main constraints on increasing the productivity of this zone are:

(a) a shortage of labour at critical points in the farming year which limit the area that a family can handle. The limit which labour availability puts on production in a land abundant area is more acute than in the forest because of the much more clearly defined seasons which lead to sharp peaks in labour demand;

(b) poorly developed infrastructure which limits input distribution and crop marketing. This in its turn constrains the use of purchased inputs to counteract labour shortages; and

(c) soils which are deficient in N and P and quite often in a number of minor nutrients also.

Available Technology to Overcome the Labour Constraint

A number of technical options are known which could help to overcome the seasonal labour constraint which limits the size and productivity of farms in this zone. The two peaks on which attention has been focussed are land preparation and weeding. These options can be broadly divided into those involving mechanisation and those involving purchased chemical inputs.

Mechanisation

In order to extend the area under cultivation in thinly populated areas there are three technologies on which most attention has been focussed:

(a) the use of tractors. This option has received greatest attention, but three main problems have been encountered with the use of tractors for land preparation in this zone. The first is the high cost of land clearing in the wooded areas which typify this zone. For hand cultivation trees can be lopped or killed by ring barking. For tractor cultivation they have to be uprooted. By hand this
activity demands large labour investments which undermine the purpose of mechanisation. The use of heavy machinery has proved too costly in relation to the crops which are suited to mechanisation (i.e. maize and groundnuts). In the shallow soils which typify much of this zone it has also proved difficult to clear without causing damage to the topsoil. The second is linked to the first in that although these soils are not as fragile as those of the forest zone the use of many of them on a continuous basis requires high levels of inputs and soil management. Without these there is often a dramatic decline in yields after three or four years and the cleared land is then abandoned for some years. Clearing costs have therefore to be amortized over a limited number of cropping seasons. When such land is abandoned it often reverts to the grass Imperata cylindrica which is extremely difficult to control by mechanical means. The third problem is the bunching of tasks caused by the clearly defined seasons. This limits the time that tractors can be involved in cultivation for easing of labour bottlenecks. Yields are more closely linked to correct planting dates in this zone, as compared to the forest, and can be adversely affected by delays in land preparation when tractors have to be shared;

(b) the use of ox-powered cultivation. This technology faces the same problems of land clearing and continuous cropping as tractor use. In addition this is a major tsetse fly zone (which is one reason why parts are thinly populated) and not only are there few cattle, but many people are unfamiliar with their management. As tsetse are controlled then ox cultivation can be encouraged but its use is unlikely to take off as rapidly as in dominantly grassland areas with few problems with land clearing and a long tradition of cattle keeping; and

(c) the development of ox-powered weeding. In areas where ox cultivation can be successfully introduced it can also be used for weeding. The potential for this is somewhat limited in this zone because of the prevalence of mixed cropping and of root crops, particularly yams, which do not lend themselves to inter-row cultivation by oxen.

The Use of Chemicals

Two groups of chemicals can be used to offset the peak labour constraints, these are herbicides and fertilizer. Herbicides can be used in two ways;

(a) minimum tillage techniques using herbicides to replace cultivation. This is a truly high input system, not only in terms of purchased equipment and chemicals, but also in its requirement for sophisticated management. Trials carried out by agricultural staff in Nigeria with this technology have not been successful. Yields fell and serious weed problems were encountered. Absolutely dependable supply, sophisticated localised research (because of differing weed and soil conditions) and a high level of extension
support are essential for this approach. These are not common features of this zone. Cost factors are obviously important and farmers are likely to be reluctant to become dependent upon a farming system which is so sensitive to input and output prices over which they have no control;

(b) weed control in conventionally cultivated plots. This is a more intensively researched technology than that for minimum tillage. Again it is dependent on regularly available, timely supplies and of good technical support services to train extension staff and farmers. With a variety of crop mixes, a range of weeds and frequent changes in product it is essential that staff be in a position to provide sound technical advice, and financial analysis if this technology is going to benefit farmers. The absence of these factors accounts for the extremely low usage of herbicide in this zone. The technical knowledge is available but service and financial constraints render it impractical for most farmers at present. To change this situation will require that these constraints be removed which is an institutional rather than a technical challenge.

Fertilizers can be used on existing farms to increase output without increasing the area which has to be cultivated or weeded. The use of fertilizer does not require equipment for application and its use is less sensitive to technical error than herbicides. Not only does fertilizer increase output per person day in the year in which it is used, but it may also extend the period for which a piece of cleared land can be used and therefore allow for the reallocation of some labour from land clearing to other productive enterprises. It is for these reasons that it is often the most popular technical innovation in this zone, when supply is timely and input and output price ratios are favourable. Its specific impact will be considered under the crop sections.

Experience of Bank Funded Projects with Overcoming the Labour Constraint in the Sub-Humid Zone

Mechanised Cultivation

The five projects selected as representative of this zone are:

Nigeria: Lafia ADP
Nigeria: Ilorin ADP
Nigeria: Oyo North ADP
Cote d'Ivoire: Dabakala/Katiola RDP
Benin: Zou RDP

The design of these projects indicated some degree of appreciation of the labour constraint. All included land clearing components to facilitate mechanised land preparation. The Nigerian projects planned for
this to be carried out by heavy earth moving equipment, whilst in Cote d'Ivoire and Benin it was planned to be done with hand operated winches and power saws.

The projects also promoted mechanised cultivation. The Nigerian projects all operated tractor hire units. In the Cote d'Ivoire and Benin the plan was to introduce ox cultivation in areas where cattle keeping is not traditional and the use of working oxen is in its infancy.

A common and striking feature of all of these initiatives was that they were planned to touch a small fraction of the cultivated area. Table 2:1 gives some indication of these proportions.

Table 2:1 Targets for Mechanical Land Clearing and Cultivation and Total Areas Farmed (areas in ha)

<table>
<thead>
<tr>
<th>Project</th>
<th>Total Area to be Mechanically Cleared Over 5 Years</th>
<th>Area to be Mechanically Cultivated as Project Initiated</th>
<th>% of Annual Cropped Area to be Mechanically Cultivated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ilorin</td>
<td>300,000</td>
<td>7,200</td>
<td>2.4</td>
</tr>
<tr>
<td>Lafia</td>
<td>150,000</td>
<td>4,000</td>
<td>2.7</td>
</tr>
<tr>
<td>Oyo</td>
<td>180,000</td>
<td>8,000</td>
<td>4.4</td>
</tr>
<tr>
<td>Dabakala/Katiola</td>
<td>36,000</td>
<td>1,400</td>
<td>4.0</td>
</tr>
<tr>
<td>Zou</td>
<td>273,000</td>
<td>1,500</td>
<td>0.5</td>
</tr>
</tbody>
</table>

(Source: World Bank Staff Appraisal Reports).

In practice none of the SAR targets was met. Although the impact of the clearing and tractor hire units was peripheral to agricultural production in the areas concerned, these activities absorbed a disproportionate amount of project physical and human resources. In the case of Oyo the project staff perceived tractorisation as the one really viable technology which they had to offer (a tractor is the project logo) and focussed their efforts on the 5% of farmers using this technology.

The second feature which was common to the Nigerian projects was the large subsidy which was required to attract farmers to use the services which were offered. Despite good management, new equipment and well funded support facilities the overt subsidy varied between 60% and 90%. There was also a substantial additional subsidy deriving from the overvalued currency and the government subsidy on fuel. These three projects have added to the well recorded history of the failure of public tractor hire services in the developing world. They have further highlighted the serious problems of tractor mechanisation in heavily wooded areas in which shifting cultivation
is still the principal means of restoring fertility and where initial soil fertility is comparatively low. A detailed review of the issue is contained in the Bank's report "Agricultural Mechanisation: Issues and Policies" (1986).

The Cote d'Ivoire and Benin projects highlight the pioneering nature of their interventions in ox cultivation. In the first, the SAR records the presence of 28 teams amongst 18,000 farming families and in the second less than 100 teams amongst 76,000 farming families. One project was planned to introduce 200 pairs of working oxen over 5 years and the other 300 pairs. Hopefully this will provide a more adequate demonstration of the potential of this technology as well as highlighting the constraints facing farmers who want to extend their cultivated area through the use of oxen. It is of interest that in a similar ecological zone in Uganda, but one with no tsetse and with a long history of cattle keeping, the number of ox plows in use grew from 282 in 1923 to 16,000 in 1938 and 70,000 in 1969. For the first twenty years of this expansion there was no significant government intervention, and farmers just responded to a technology which helped them to add cotton to their existing food crops.

In Nigeria there has been negligible development of ox cultivation in this zone and the Bank is considering its encouragement under new projects now in the pipeline.

The Use of Chemicals

Minimum Tillage. Two of the Nigerian projects (Oyo and Ilorin) were expected to use minimum tillage techniques which included rotary slashing and herbicides for seed bed preparation. One project, Oyo north, also planned to have manually operated minimum tillage using herbicides only. In the event the agricultural staff were not able to develop either of these techniques effectively with regard to weed control, yields and costs as compared to conventional methods and so they were not put into practice on farmers' fields. The technology was developed by IITA at a time of highly distorted herbicide prices resulting from currency over-valuation. It has yet to be adequately tested under farmer conditions, and past project experience with technologies which are based entirely on imported inputs would indicate that this technology is unlikely to provide a viable basis for widespread use to overcome the labour bottlenecks in this zone.

Weed Control. Apart from the two projects which planned to use herbicides as part of a minimum tillage package there was no provision for the use of herbicides for general weed control. In the event both Oyo and Ilorin projects imported herbicides which were not used for minimum tillage but sold for general use on maize in pure stand. Because of the large distortions in the exchange rate the herbicide provided a cheap alternative to employed labour for larger scale farmers using mechanised land preparation. The jump in prices following devaluation has made this a much less attractive option. In the early days of these projects the cost of herbicide for 1 ha of maize (which eliminated the need for one weeding) cost the equivalent of 5 days labour. The current cost is the equivalent of 30 days labour. This initiative only influenced a small fraction of the cropped area.
Fertilizer. The three Nigerian and the Benin projects planned on increasing the supply of fertilizer in the project areas. The details are given in Table 2:2.

Table 2:2 Anticipated Fertilizer Use and Area Affected

<table>
<thead>
<tr>
<th>Project</th>
<th>SAR Estimate Project Sales of Fertilizer in Year 5/tons</th>
<th>SAR Estimated Application kg/ha</th>
<th>Number of Cultivated Area Affected ha</th>
<th>% of Total Cultivated Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oyo</td>
<td>9,025</td>
<td>300</td>
<td>30,053</td>
<td>16</td>
</tr>
<tr>
<td>Ilorin</td>
<td>13,693</td>
<td>200</td>
<td>68,465</td>
<td>23</td>
</tr>
<tr>
<td>Lafia</td>
<td>13,900</td>
<td>200</td>
<td>69,500</td>
<td>46</td>
</tr>
<tr>
<td>Zou</td>
<td>3,300</td>
<td>150</td>
<td>22,011</td>
<td>8</td>
</tr>
</tbody>
</table>

(Source: World Bank Staff Appraisal Reports).

Fertilizer was therefore expected to play a much greater role in increasing output per unit of labour than any of the other project interventions in this sphere. Its anticipated impact on productivity and its financial and economic viability will be considered under the specific crop sections.

To summarise the situation with regard to overcoming the labour constraint in this zone it is clear that there are a number of well developed technologies which can be used to increase labour productivity, but all except the use of fertilizer face formidable constraints to their application which many years of project and other government initiatives have failed to overcome. Only in areas of exceptional soil fertility which provide the prospect of long-term continuous cultivation does tractorisation offer any prospect of a viable breakthrough for the large scale farmer. In addition there need to be good support services and plentiful opportunities for tractor work other than cultivation. For small scale farmers there is scope to further investigate the potential and constraints on the use of oxen.

Available Technology to Overcome the Soil Fertility Constraint

As has been noted above one of the constraints on mechanical cultivation in this zone is the need for frequent fallowing to restore soil fertility. In many areas cultivation is maintained for 4 years and this is followed by 4 to 8 years of fallow. Because land has not been a serious constraint in this zone in the past there has not been a strong demand from farmers for alternative strategies. Any move to mechanise cultivation changes that situation as farmers attempt to maximise their return on the high cost of initial land clearing.
Research on this subject has been carried out for many years. Earlier efforts involved the use of green manures and composting. A combination of these techniques enabled workers to maintain soil fertility, but labour demand is high and such technology does not match most farmers' needs in this zone at present. More recently IITA has experimented with the use of rows of trees between the annual crops which is known as alley cropping. IITA is situated within this zone so that its work at Ibadan is applicable to this sub-humid area.

Alley Cropping

Detailed descriptions of the system are available in a Bank internal paper "Agro-forestry as a Possible Sustainable System in the Humid Tropics" by Lal. A further critique of the underlying assumptions is given in ICRAF Working Paper No. 40 of Dec. 1986. Work to date shows that alley cropping has the following features:

(a) it slows down the rate of crop decline under continuous cultivation, but does not by itself eliminate that decline;

(b) it contributes to soil and water conservation; and

(c) it raises labour demand during the growing season by 50% over conventional production systems. 5/

The Use of Fertilizer

In addition to the long-term soil fertility maintenance work being carried out by IITA, attention has also been given to ameliorating the constraints imposed by low soil fertility through the use of fertilizers. Whilst the main focus of the work has been on N and P there is good evidence from experiments carried out in Nigeria by IITA/IFDC that minor nutrient deficiencies can also place a major constraint on increasing yields. Sulphur, zinc and boron are among those which deserve close scrutiny in situations in which conventional fertilizers do not give the kind of yield increases which could reasonably be expected. Widely varying response rates to P in particular highlight the complexity of the soil situation in parts of this zone. In a number of areas there is a need to ensure that adequate data on responses to fertilizer exist before there is a program to rapidly increase fertilizer use.

Experience of Bank Funded Projects with Overcoming the Soil Fertility Constraint in the Sub-Humid Zone

None of the projects being reviewed included any work with alley cropping.

Four of the projects included conventional fertilizers, and one SAR (Ilorin) specifically highlighted the need for work on minor nutrients. In the event this work was not carried out and in all three of the Nigerian projects there was evidence that crop responses to fertilizer were being limited by other nutrient deficiencies, but no serious steps were taken to address the problem.

In only two of the projects, Oyo and Ilorin, was any proposal made to move away from the traditional fallow system for the restoration of soil fertility. In these two the minimum tillage proposals were expected to eliminate the need for fallow. In the event they did not work out, and there was consequently no alternative strategy to falling suggested to farmers.

**Crop Production**

A wide range of crops is grown in this zone and different ones are dominant from one area to the other. Of these there are four crops which in one combination or another constitute the main core of the farming pattern. These are yams, maize, cassava and sorghum. Most cropping is in mixed stands and as has been highlighted earlier the main constraint on increasing output is a shortage of labour at certain key points in the farming year. The viability of any technology which is proposed for increasing the output of these crops needs to be assessed in the light of this constraint. This is also the zone in which there has been considerable development of cotton growing in recent years which has a major impact on the farming system of those farmers who are involved. This development has received detailed attention in other Bank publications and is outside the scope of this particular study.

**Yams**

The technology of yam production in this zone is not strikingly different from that in the forest zone described on pages 10 to 12. Yams setts are a major investment in this zone as in the forest, so that proposals to increase plant populations in order to raise production per unit area of land while depressing output per yam sett are unlikely to be seen as attractive by many farmers. The technology of minisetts works in this zone, but its labour requirements need to be analysed carefully in any situation to ascertain how labour at peak periods can be reallocated to this activity. This work has not been carried out in most of the zone and conditions will vary according to local crop combinations. Only after there has been an analysis of labour demand and availability in a given area will it be possible to judge whether the minisett technique offers an attractive technology.

Staking is not as critical for yam production in this zone as in the forest because of higher levels of insolation and lower levels of anthracnose. Staking still does have a significant impact on yields and offers the most straightforward way of raising production. Staking and the accompanying training of the young vines places a high demand on labour at a time when weeding is critical to the production of all the crops in the system. Any new technology intended to improve on staking must deal with this labour clash. One system in Nigeria does this by using a combination
of yams and a strong stemmed sorghum. After the sorghum grain is harvested the stems are shaped into a trellis over which the yams are able to grow. The development of in-field stakes seems to be fundamental to any practical technology for larger scale yam production, and sorghum provides an excellent source of such material.

Yams often give good responses to fertilizer in this zone and there is less complaint from farmers about fertilizers making yams “watery”. Response ratios are similar to those in the forest zone.

Experience of Bank Funded Projects with Yam Production in the Sub-Humid Zone

Yams are grown in all the areas covered by the five projects being reviewed in this study. All but the Benin project included yams as a major project component. In the three Nigerian projects yams were expected to provide the major benefit flow. In the Cote d'Ivoire they dominate the food crop benefit stream.

Two quite distinct strategies were proposed for Nigeria and Cote d’Ivoire and these will be considered separately.

Nigeria

Two techniques were planned to bring about a major increase in yam production per ha in the three projects. These were:

(a) increasing the plant population from 6,000 to 8,000 stands per ha and using larger setts; and

(b) applying fertilizer. In Oyo and Ilorin this consisted of 30N 30P 30K and in Lafia of 52N 30K.

Work at IITA has shown that increasing sett size increases yields per ha but reduces the multiplication ratio, i.e. lowering the weight of yam produced per weight of yam planted. Increasing the population per ha also results in a lower yield per yam sett planted (this is spelt out in the Ilorin report). In these projects the extra 2,000 plants per ha were expected to provide the following incremental production:

<table>
<thead>
<tr>
<th>Location</th>
<th>Incremental Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ilorin</td>
<td>1.6 tons</td>
</tr>
<tr>
<td>Oyo</td>
<td>2.0 tons</td>
</tr>
<tr>
<td>Lafia</td>
<td>1.8 tons</td>
</tr>
</tbody>
</table>

No estimate was made of the effect of planting the same weight of setts over a greater area, which is farmers’ normal practice.

The other innovation, fertilizer, was expected to provide the balance of the incremental production.
Because land is not a constraint in this zone farmers were not prepared to sacrifice production per weight of yam sett for the sake of increasing yields per unit of land. The proposed increase in the number of yam mounds does not fit well with the pattern of yam/sorghum intercrop in which the sorghum provides the staking material. In consequence these three projects did not influence yam production through any changed agronomic practice, but they did bring about an increase in yields through fertilizer use. These increases were somewhat less than those put forward in the SAR.

This experience highlights the necessity to assess the viability of a technology in the light of the farmer's objectives at a given point in time. Farmers were aiming at maximising returns per yam sett and per unit of fertilizer, the project's objectives were maximising output per unit of land.

The SAR's did highlight the problem of proposing any staking method other than the use of sorghum stalks, the labour requirements of any alternative are described as 'prohibitive'.

Cote D'Ivoire

The strategy adopted under this project is quite different to that in Nigeria. No change is proposed in the existing plant population of 5,000 per ha and it is not proposed to promote the use of fertilizer. Two changes in farmers practice are suggested. The first is to increase the frequency of weeding and the second is staking. Yield increases from these two innovations are expected to be 2 tons per ha for early yam and 3 tons per ha for late yam. Much of the yield increase is attributable to the staking. These estimates appear to be well within the range of experimental experience in the zone. What is less clear is the source of the major increase in labour which this technology requires, mostly at a time when there is a serious bunching of tasks on the range of crops growing in the area. The problem is rendered more acute in that the improvement in output of other crops covered by the project is also dependent upon intensified labour use. Staking and training the vines would require a minimum of an extra 50 person days per ha, and in less wooded areas the demand would be much higher. Two extra weedings would require an additional 30 person days per ha. In the absence of any strategy to overcome existing labour bottlenecks this does not appear to offer a viable technology for a family unit which in the project area is estimated to have a total of 2.5 labour units to cover 2.2 ha of farm in an area with a clear-cut, limited planting season.

Maize

This zone is more favorable for maize production than the forest zone. Temperatures above 30°C inhibit early plant growth and short days limit the radiation which is an essential prerequisite of high maize yields. Typically yields in the hot equatorial zone are a half of those under similar production conditions in the temperate areas. Within the tropical zone there are also wide variations in potential maize productivity which depend on temperature, radiation and water availability. Yields of maize under research conditions at IITA in Ibadan (in the low altitude equatorial zone)
are not only much lower than at CIMMYT in Mexico (in the highlands at 20°N) but also much lower than sub-stations three hundred miles north with different patterns of temperature and radiation.

There is no doubt that technology exists which can raise maize yields in this zone. The potential for doing this varies widely as a result of ecological factors and it is particularly important to analyse those factors which are constraining maize yields in a particular area before devising a maize improvement program. Recommending fertilizer rates developed under conditions with high levels of insolation, warm days and cool nights for an area with the opposite conditions could lead to serious losses by farmers.

The following are the biological factors which might limit maize yields and determine what technical change would be most advantageous in various parts of the sub-humid zone:

(a) rainfall patterns. There are two patterns of rainfall in this zone which have an important impact on maize yields. In the weakly bimodal areas there is a dip in rainfall in mid season which could coincide with the tasseling (flowering) of the maize. Experimental evidence is that two days of serious water stress at tasseling can cause a 22% loss in yield. More prolonged stress can result in a 50% fall in the harvest index. It is therefore critical, when planning a strategy which may involve a change in variety, to ensure that the flowering time of any proposed improved variety does not coincide with a period of above average risk of drought. The second pattern occurs where there is a long monomodal system which involves the risk of maize ripening under wet conditions. Resistance to cob rots and "in husk germination" may then become one of the most important of selection criteria if maize growing for grain is being encouraged;

(b) soils poor in N and P and deficient in sulphur and zinc are typical of this zone. Efforts to increase maize yields through improved agronomy without addressing the fundamental problems of plant nutrition are likely to have limited success in such soils. This is a widespread problem in this zone and P deficiency may be so severe as to preclude successful maize growing if it is not rectified;

(c) soil temperatures. Because of the hot dry season in this zone soil temperatures at the recommended time of planting may be over 36°C which seriously impede the early growth of maize. Despite the other disadvantages of late planting this may be the better option under these circumstances and planting dates should be scrutinised in the light of soil temperatures, which may account for existing farmer practice with regard to date of planting;
(d) insolation. In the wetter areas of the zone the hours of full sunlight can fall to 4 hours a day at the height of the growing season and reduced radiation can put a serious limit on yields. Fertilizer recommendations, particularly for more advanced farmers, need to be reviewed in the light of this constraint to avoid too sharp a drop in response ratios at higher levels of application;

(e) striga. This is a parasitic weed of cereals to which maize is particularly susceptible. There is no treatment for it and it will reduce yields by 90%. In areas where it is endemic the tolerance of a given cultivar becomes the most important feature of selection. As population pressure increases striga is likely to become the major constraint on maize growing in this zone.

In general the best areas for maize are those at the lower rainfall end of this zone provided that it is in a monomodal pattern. Because of the varying impact of these different factors maize growing in this zone ranges from that of a minor crop used for green cobs to an important component of the farming system. The following notes on technologies to raise production will focus on enterprises in which maize is grown in pure stand, or is the dominant component of a mixture, and from which the product is dry grain. The analysis will consider the choice of planting materials, field practices and the use of purchased inputs.

**Planting Material**

Three broad types of planting material are available for maize.

(a) "local" seed selected by farmers over a number of generations for features which they particularly value;

(b) improved open pollinated varieties released from research stations. These can be grown from home kept seed for three or four generations before new seed needs to be purchased; and

(d) various conventional and non-conventional hybrids for which new seed should be purchased each season.

The advantage of improved open pollinated seed is usually its increased resistance to disease, which has been a focus of research effort. Improved varieties for this zone should have resistance to rust, blight and streak. The yield improvement to be gained from simply switching seed (with no other change in husbandry) will vary according to the severity of disease challenge and the adaptation of local cultivars. It will usually be of the order of 100 to 200 kg per ha. The seed requirement for 1 ha is 25 kg. If improved seed costs three times the price of the harvested grain then at the lower level of response (100 kg) the initial purchase does not provide the farmer with an attractive return. It is for this reason that governments
often subsidise the price of open pollinated improved maize seed, because widespread long term use can reduce disease incidence and raise overall average yields by several percentage points.

Hybrid maize does offer the opportunity to make a substantial increase in yields because of the phenomenon of hybrid vigour. The yield advantage declines with increasing stress on the plants (from poor nutrition, water shortage or inadequate weed control). The actual increment which would be achieved by switching from a local cultivar to a hybrid under poor cultural conditions would depend upon the severity of the stress to which the plants are subjected. Hybrid seed in Africa often costs about 10 times the price of grain (in the U.S. it costs 30 times more) so that it usually only becomes attractive to farmers when they can supplement the change of seeds with additional nutrients and improved management which can draw out the potential of this material. In fact the high cost of the seed often acts as a stimulus to farmers to increase their allocation of other resources to the crop and thereby produce an exaggerated impression of the impact of the seed itself.

Field Practices

Date of planting, plant populations and weeding are the three agronomic practices which have the most influence on maize yields.

At the time of germination maize roots have a high demand for oxygen and consequently early plant growth can be severely limited if soils are soaked by a succession of rainy days so that air is largely replaced by water. Stunting at this stage has a substantial effect upon final yield. It is for this reason that early planting, particularly in heavier soils, is a major factor in determining maize productivity. In light, sandy, freely draining soils it is less critical. Farmers are mostly well aware of the need for early planting, but in areas in which the land is too hard to cultivate in the dry season they are not able to plant at the beginning of the rains. Cultivating and planting a hectare of maize by hand requires about 40 man days. With two adults in a family, and a normal pattern of illness as the rains begin, it takes at least a month to complete 1 ha of land preparation and planting. In consequence some 75% of the maize will be planted after its optimal time. In light sandy soils in which cultivation can be carried out in the dry season the problem is less serious. For the great majority of farmers who rely on hand hoeing there is at present no applicable technology available to assist them to plant all of their maize at the optimum time if land is too hard for dry season cultivation. The best approach is to investigate the possibility of developing farm plans in which the harvesting of the preceding crop (e.g. yams, groundnuts) provides a rough seed bed into which maize can be planted without prior cultivation at the beginning of the rains. This will release labour to deal with the early weeding which is essential for such a system.

Plant populations have a major effect on maize yields within a certain range of plants. There is, however, no universal optimum. The two main determinants are plant type (large or small) and soil fertility. There could thus be two different optima within one village if a short early type and a long season type are both being grown, and if some fields are poor and
others are well manured or fertilised. On a poor soil plant populations should be lower (typically about 25,000 per ha) and on a richer soil higher (typically about 35,000) using long season plants in pure stand. For smaller, short term varieties the number should be increased by 5,000 plants.

Because of the maize plant’s need for high levels of solar radiation to maximise yields the best configuration of plants in areas of limited insolation is in groups with quite wide gaps in between. For large maize plants a group of 3 plants at 90 cm apart in the row and 90 cm between rows is typical of such a planting pattern where soil fertility is reasonable. For poor soils this distance would be increased to 1 m. Plant populations can often be increased considerably without lowering yields significantly, but this reduces stem thickness and sometimes leads to increased losses from stem borers. High populations fit well with systems in which the stover is a valuable livestock feed, but this is not the usual situation in the sub-humid zone.

The main problem with achieving adequate plant populations is that the infilling of gaps where plants have failed to establish seldom produces robust plants (because of the delayed planting which is inherent in this activity). In consequence farmers ought to plant more seeds at each stand than the number of plants which they ultimately require, and thin out the surplus plants after two or three weeks. Unfortunately, the thinning exercise is required at one of the busiest periods in the farming year and is a time consuming task and is therefore only practical in situations in which labour is not a major constraint. One alternative strategy is to reduce the distance between stands in the row and plant alternate stands with 2 and 3 seeds respectively, and not advocate thinning. Stands every 70 cm planted in this way should give a final total population of around 36,000 with no major gaps and no stands with more than three plants. The choice of actual spacing needs to take account of the farmers’ ability to carry out timely thinning rather than aiming at an ideal which is not within their capacity to achieve.

The yield increment to be obtained from changing plant populations will obviously depend on the existing practice and the level of soil fertility. One of the more fruitful areas for introducing farmers to a yield enhancing technology is where fertilizer is being adopted which may allow of higher plant populations than those to which farmers are accustomed under less fertile conditions.

Weeding

There are substantial benefits to be gained from weeding maize within the first three weeks after planting, and severe competition at this time can depress yields by up to 25%. Unfortunately farmers who rely solely on hand hoes are fully engaged in land preparation at the time that the first planted maize requires weeding. They therefore have to make the choice between opening additional land or weeding maize at the optimum time. In general farmers reckon that extending the size of the farm and delaying weeding provides the better return to labour.
Technology in the form of herbicides is available but is often not a viable option for farmers because of shortage of cash, poor supply systems and poor benefit: cost ratios. Therefore weeding of maize remains an intractable problem in many situations which can be studied in terms of the whole farming operation to ascertain whether there is a possibility of making a profitable change in cropping patterns which can ease the bottleneck on early maize weeding.

The Use of Purchased Inputs

Fertilizer. Maize is particularly sensitive to a deficiency of P and in a number of areas in the humid zone it will not grow unless this element is provided, usually as fertilizer. Because maize has a higher grain index (the ratio between grain and vegetative parts) than millet and sorghum it usually gives a better response to N than either of the other main grain crops of Africa. Because of these two factors maize is often given priority among food crops in the allocation of fertilizer.

Yields without fertilizer are dependent on the level of soil fertility and are typically between .9 and 1.5 tons per ha (the national maize yield for India is 1.05 tons per ha). If a fertilizer is used which supplies adequate P then a farmer should expect to obtain from 10 to 12 kg of grain from each kg of N which the fertilizer contains, in the range of 30 to 90 kg N per ha. This applies to open pollinated material. Using a hybrid the ratio could rise to 15 to 20 kg of grain per kg of N. If farmers are obtaining much less than these figures there is a real possibility that there are other nutrient deficiencies which require attention (e.g. K, Zn, S). In practical terms this means that a farmer applying fertilizer containing 60 N 30 P on an open pollinated maize would expect to obtain between 600 and 700 kg of extra grain. On a hybrid the figure should be about 1,080 kg. The purchasing, transporting and application of fertilizer all require labour and possibly transport charges. An equivalent of two man days per bag is an average estimate. The additional crop also requires harvesting, transporting, storing and shucking. There are obviously wide variations in the amount of carrying to be done, but a figure of one man day per 60 kg of grain to cover these activities represents a reasonable average.

Prices for fertilizer vary greatly depending on the type used, the distance from the port and the efficiency of the distribution system. The table 2:3 provides two examples from Ghana and Nigeria of the current costs of the use of fertilizer on maize. It also indicates the price for grain which a farmer would need to receive in order to obtain the 2:1 benefit cost ratio usually required to encourage the adoption of a technology requiring extra expenditures.
<table>
<thead>
<tr>
<th>Country</th>
<th>Available Fertilizer</th>
<th>Quantity Required Kg</th>
<th>Cost of Fertilizer</th>
<th>Incremental Cost of Labour Open Pollinated</th>
<th>Incremental Cost of Labour &amp; Seed Hybrid</th>
<th>Total Cost Open Pollinated</th>
<th>Total Cost Hybrid</th>
<th>$ Price Required to Give a 2:1 B:C Ratio on 1 Ton of Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghana</td>
<td>20-20 Sulphate of Ammonia</td>
<td>150</td>
<td>45.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nigeria</td>
<td>15-15-15 CAN</td>
<td>200</td>
<td>50.00</td>
<td>23.00</td>
<td>42.00</td>
<td>96.00</td>
<td>116.00</td>
<td>295.38</td>
</tr>
<tr>
<td>Nigeria</td>
<td>15-15-15 CAN</td>
<td>115</td>
<td>22.00</td>
<td>23.00</td>
<td>42.00</td>
<td>96.00</td>
<td>116.00</td>
<td>295.38</td>
</tr>
</tbody>
</table>
If the 2:1 B:C formula is only applied to the fertilizer and a 1:1 ratio is used for the labour then the prices required are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Open Pollinated</th>
<th>Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghana</td>
<td>265.82</td>
<td>182.65</td>
</tr>
<tr>
<td>Nigeria</td>
<td>260.00</td>
<td>179.00</td>
</tr>
</tbody>
</table>

The open pollinated price is well above import parity price at either site and with either method of calculation. For the hybrid maize the price required to give a 2:1 B:C ratio to both fertilizer and labour is above import parity. When the 2:1 formula is applied to fertilizer only the price comes near to import parity at late 1988 prices but not for 1987 or predicted 1990 prices.

These examples illustrate the fact that despite good response ratios to fertilizer it is not easy to obtain a return to its use which provides farmers with an attractive incentive at undistorted prices. This underlines the need to use the most efficient combinations of nutrients, the lowest cost source of nutrients (usually high analysis fertilizers if there are long haulage routes) and optimum methods of application. The figures also illustrate why many governments subsidise fertilizer in order to encourage its uptake.

**Pesticides.** There are three pesticides used on maize in this zone which can influence total output. These are:

(a) seed dressing. This is used to limit damage from both seed and soil borne pathogens. The cost is small and although it seldom has a major impact on yields it does help to achieve good plant populations, thereby justifying its use;

(b) chemicals to control stem borers. The impact of these pests varies widely between seasons and locations and the attractiveness of their control fluctuates accordingly. Usually the systematic use of a pesticide is only justified in areas with a history of persistent and serious losses; and

(c) storage chemicals to reduce weavil damage. Products are available which are applied directly to the grain and which comply with WHO health standards. They are effective when correctly used but require that the grain shall be at least husked and better still, shelled before storage. This may require a complete change in existing practices and involve problems of grain moisture levels (the dry husks help to lower overall moisture) and labour constraints. If these constraints can be overcome and farmers are using weavil susceptible varieties then these chemicals can result in savings of 10 to 20 per cent of grain over a ten month period.
Herbicides. For maize being grown in pure stand there are herbicides available which, when properly applied, will give good control over a wide range of weeds for at least the first six weeks of growth. These can be applied with simple hand held equipment. It is not possible to quote any universally applicable cost: benefit analysis for these products. However, if the cost of herbicide and the depreciation of the pump is more than the cost of 15 man days of hired labour then herbicide is only likely to be attractive to commercial farmers who cannot mobilise sufficient hired labour to achieve timely weeding.

Experience of Bank Funded Projects with Maize in the Sub-Humid Zone

All of the projects under review were expected to bring about an increase in maize yields per unit of land. All included one or more of strategies aimed at changing planting material, agronomic practices and the use of inputs.

Planting Material

Only the Cote D'Ivoire project made no proposal to change some part of the maize seed used by farmers. In Zou, Ilorin and Oyo it was proposed that there would be two maize 'packages'. In each case only the advanced package was to include an open pollinated improved variety. In Lafia there was only one 'package' and that was to include an unidentified improved seed. The projects had to rely on sources of foundation seed outside their control, and were under pressure to maximise production from their seed farms at the expense of quality. In consequence the seed components had little impact on yields, but served to highlight the need for better conceived seed policies if this particular intervention is to be effective in the future.

Agronomic Practices and Input Use

The main focus of technical change in these projects is the plant population and the use of fertilizer. There are a range of different plant populations recommended, with one going as high as 62,000 plants per ha. There is no evidence that in the event the projects have had any significant impact on the plant populations being used by farmers for maize. In part this reflects the range of soils and varying local climatic conditions which govern farmers' choice of plant populations combined with the fact that a lot of maize is grown in mixed stand and not as a sole crop as reflected in the numbers proposed under the projects.

Three of the projects were expected to promote increased fertilizer use and did achieve this objective. The anticipated response to fertilizer was of 25 to 31 kg of grain per kg of N but actual yield increases were well below this figure. This was particularly the case in Ilorin and Oyo where it appears that minor element deficiencies frequently depress the response of maize to the major nutrients supplied in the fertilizer.
Cassava

Cassava is quite widely grown in this zone but is less prominent in the total food supply than in the forest because of the wider range of other crops which are available. It is normally planted as an intercrop at the end of the rotation and leads into the fallow from which it is harvested as required. It is less likely to be treated as a major crop to be allocated priority in terms of labour or inputs than is the case in the forest zone. The technologies for raising yields are the same as those described on pages 5 to 9 but their application will depend upon the role which cassava plays in the farming system. This is particularly true of varietal selection. High yielding, early maturing, slightly bitter varieties will be poorly suited to farmers who want to use cassava as a fallback food security crop in an abandoned piece of land at some distance from their homes. This situation would require a long-term plant with a tall frame, tubers which store well in the soil and which are very bitter to discourage wild animals in this fairly thinly populated zone. As always, applicable technology needs to be tailored to farmers’ requirements, but the choice of healthy planting material of the right degree of maturity provides a means for improving yields whatever the place of the crop in the farming system.

Experience of Bank Funded Projects with Cassava in the Sub-Humid Zone

Three of the projects, Oyo, Ilorin and Lafia made proposals for increasing the production of cassava. In two of the projects it was expected to supply the second largest stream of benefits and the third largest in the other. In all three it was proposed that farmers should be encouraged to switch to the IITA releases, which are resistant to mosaic, and apply fertilizer to the crop.

In the event the projects did not give priority to cassava, few improved cuttings have been distributed and farmers have not allocated fertilizer to this crop. New initiatives in these areas are continuing to investigate the potential for switching cassava varieties, but are assuming lower estimates of yield change than were used in these projects.

Sorghum

There are three broad types of sorghum grown in this zone. These are:

(a) for direct human consumption as flour. These are usually white and with a hard endosperm;

(b) for brewing beer. These are often red and are bird resistant because of their bitter flavour; and

(c) for providing in-field staking for yams. These require sturdy stems resistant to rotting.
All of these sorghums face three groups of constraints to their production in this zone. These are:

(a) high temperatures at planting time;

(b) pests and diseases. The most important are shoot fly and stalk borer during early development; leaf diseases and striga at mid-term growth; and midge and grain molds at flowering and maturity; and

(c) low levels of soil fertility.

Local cultivars have been selected over long periods of time with early seedling vigour at high temperatures and tolerance of leaf diseases and striga. They are mostly daylight sensitive so that they can be planted early in the rainy season (whenever it starts) and so avoid shoot fly and yet not mature until after the rains have finished and so avoid grain moulds. It has proved difficult to breed new, higher yielding varieties which also demonstrate all these qualities but outperform local material. Most work has been focussed on the sorghums grown for food and little attention has been given to those used for brewing and yam staking. Despite many years of research and breeding there has been little adoption of any new material by farmers. The revised and reformed approach by ICRISAT in West Africa combined with more reliance on locally adapted material in national programs is resulting in the appearance of new releases of sorghums for food. The following notes on technologies to raise production will consider the choice of planting materials, field practices and the use of purchased inputs.

Planting Material

Any attempt to improve upon sorghum production through a change in planting material needs to be based on a thorough knowledge of the purpose for which the sorghum is used. A short sorghum with small stems and high yields of grain for flour will be of little interest to farmers who are principally growing the crop for yam staking. The same would go for farmers seeking brewing quality. Secondly it is important to ensure that any improved material has proved its superiority under farmer conditions (i.e. low levels of fertility, high striga challenge). Large numbers of earlier releases which performed well on research stations were not able to hold their superiority on farmers fields. This situation is changing, and for farmers who want to produce grain for flour and who have above average soil conditions there will be a growing number of new varieties which might offer some advantage over traditional material.

Field Practices

Suitable planting dates for local varieties will be well known to local farmers. As these are mostly daylight sensitive their maturity is dependent upon daylight length rather than planting date. Some improved material is daylight insensitive and the date of planting is then more critical. Plant populations are dependent upon the purpose for which the crop is grown (grain or yam stakes) and upon soil fertility. Sorghum is an excellent scavenger of nutrients and will grow successfully in soils in which
maize would be a complete failure. In order to fulfill this function individual plants need to develop large root systems. Increasing plant populations in situations in which the availability of nutrients is limited can lead to declines in yield. If there is a change in fertility levels then there can be gains to changing plant populations. It is not desirable to plan for the same plant population for a whole area. Plant density has to be related to variety and soil quality.

**Purchased Inputs**

The simplest way in which to raise sorghum yields in most areas is through the provision of additional nutrients from fertilizers. Unfortunately most traditional sorghums have a low harvest index (the ratio between grain and other plant tissues) and in consequence the amount of extra grain obtained from a kg of nutrients is lower than for maize. There are obviously great variations in response ratios depending upon the severity of nutrient deficiencies but over a large population of farmers a response of 4 to 8 kg of grain per kg of nutrient would represent a reasonable average. In most sorghum growing areas of the sub-humid zone such a response does not provide an attractive return to farmers at undistorted grain and fertilizer prices and does not therefore constitute an attractive technology in the absence of subsidies.

**Experience of Bank Funded Projects with Sorghum in the Sub-Humid Zone**

Only three of the projects under review included proposals for sorghum. These are Oyo, Lafia and Ilorin. None of these proposed any change in variety or in agronomy and they focussed on the provision of fertilizer. In the event the projects laid no accent on sorghum, and fertilizer use has been concentrated on maize with its higher response ratio.

**Rice**

Throughout this zone there are areas of restricted drainage which farmers use for rice production. The description of technical innovations for lowland rice contained in pages 16 to 19 is also applicable to this zone.

**Groundnuts**

Groundnuts are a minor crop in this zone and the availability of technology for this crop will be discussed in greater detail in the section on the drier areas where they are much more important. A major difference between the wet and dry areas is the relative importance of two major diseases which limit yields. These are the virus disease called rosette and rust. Rosette resistant varieties are now available which grow well in this zone, but which have too long a growing season for the drier areas. Rosette is therefore a disease which can be largely eliminated in the sub-humid area through the use of appropriate varieties. On the other hand leaf rust which can reduce yields by 50-70% is more serious in the wetter zone and for that there is at present no resistant material available for farmers.
Technologies for increasing yields include a change in planting material to a variety with resistance to rosette, increasing plant populations and using fertilizer. There is a strong link between using a rosette resistant variety and spacing. If rosette is a serious problem it can be partly counteracted by very close spacing. This gives high yields per unit area of land but lower yields per weight of seed planted. If a rosette resistant variety is used then wider spacing can be adopted. This will lower yields per unit of land but increase output per unit weight of seed. As seed is the most expensive input into groundnut production, wide spacing will usually provide the best return to investment in land plentiful areas.

Phosphatic fertilizer can have a favorable impact on groundnut yields but response is particularly erratic. Table 2:4 gives the range of results to the application of various levels of phosphate to groundnuts in the 1,000 to 1,400 mm rainfall belt in Benin and Mali:

Table 2:4 Responses of Groundnuts to Phosphatic Fertilizer

<table>
<thead>
<tr>
<th>Site and Rainfall (in mm/year)</th>
<th>Range of Response kg Nuts/kg P2O5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meridjonou Benin (1,400)</td>
<td>0</td>
</tr>
<tr>
<td>Boukombe Benin (1,200)</td>
<td>2.4 to 5.1</td>
</tr>
<tr>
<td>Sotuba Mali (1,000)</td>
<td>0.8 to 9.0</td>
</tr>
</tbody>
</table>

(Source: ICRISAT Report).

It is therefore necessary to have well validated farmers trials in a specific area before the use of phosphatic fertilizer can be proposed as a worthwhile technology for groundnuts in this zone.

Experience of Bank Funded Projects with Groundnuts in the Sub-Humid Zone

Only two of the projects being reviewed included any proposals for groundnuts. In Zou it was proposed that there be an application of 50 kg of phosphatic fertilizer combined with a change in variety which would result in a yield increase of 500 kg/ha. The proposal was dependent upon seed production on a project farm, and with the low multiplication rate of groundnuts, could only influence a small area. As only 100 kg of extra yield could realistically be expected from the fertilizer it would appear that 400 kg were to derive from a change of variety which is a particularly ambitious target.
At Dabakala the strategy was based on better seed selection and increased plant populations which were expected to provide a 300 kg increase in yield per ha. This is a realistic objective but under these conditions it is important that attention be given to whether returns to seed or returns to land are the most important objectives of the farmer.
Background

Sorghum and millet are the two most important crops in SSA in terms of the area cultivated. The West African belt constitutes a substantial part of the total area. The population of this zone is approximately 78 million and it therefore represents an important segment of SSA agriculture.

A major constraint on crop production in this zone is the availability of water for plant growth. This is not just a matter of total quantity but of wide inter-seasonal fluctuations. As a consequence farmers have developed strategies and selected plant types which can give some protection from the impact of uncertain rainfall. Any proposals for increasing output in this zone must be assessed in the light of farmers’ needs to guard their production in an area of erratic rainfall. Proposals to move to a single cultivar rather than a mixture, to a cowpea with high grain yield but no hay, to higher plant populations which increase the chance of complete crop loss in drought years, are unlikely to be readily accepted by farmers in this zone, despite the fact that they may provide attractive returns in years of good rainfall. Strategies for increasing overall farm productivity therefore need to be linked to increasing water availability to crops and increasing household security.

Strategies for Increasing Water Availability

There are two fundamental ways of increasing water availability to plants under rainfed conditions in this zone. These are to:

(a) increase the amount of water which penetrates to the root zone; and

(b) increase the volume and length of roots to capture available water.

A common constraint on both water and root penetration is soil density. In this zone many soils lack any clearly defined structure. The exceptions to this are those soils with more than 20% of clay, but these form a small proportion of the total area. Structureless soils can severely restrict the downward movement of both water and roots. Because organic matter does not accumulate as humus under conditions of high temperature this condition cannot be changed significantly through the addition of modest quantities of organic manure. The three main ways of counteracting the problems of density in structureless soil are:

(a) by physically breaking up the top few centimeters of soil by ploughing;

(b) by slowing down the movement of water across the surface of the soil; and
(c) by encouraging the growth of strong cereal crops, the roots of which open up channels for both water and subsequent crops.

These are dealt with in more detail in the following paragraphs.

**Soil Cultivation**

The impact of ploughing or digging on plant growth and water uptake varies from one soil type to another but there is good evidence that under a range of conditions in this zone it does have an ameliorative effect on the rate of moisture and root penetration during the first four to six weeks of the rainy season, by which time the action of rain will have consolidated the soil once more. Under other conditions ploughing appears to have no significant impact on root and water penetration, although it may be beneficial in weed control. Even in those areas in which it is of proven benefit however, if often does not offer the farmer a practical technology for increasing crop production or security. This is because the soils which most benefit from being broken are those which are too hard to work before the onset of the rains. To delay planting, in order to cultivate the land following the onset of the rains, will often lead to a fall in yields which is not compensated for by breaking of the soil. Surveys of farmers in northern Nigeria showed that yield levels descended in the following order:

(a) no cultivation (best);
(b) ox cultivation; and
(c) tractor hire cultivation.

The losses were closely correlated with the relative delays in planting resulting from these three systems, which outweighed any benefits from cultivation.

In areas in which the length of the rainy season allows for some delay in planting, it may prove profitable for farmers to increase water availability by cultivating their land prior to planting. In drier areas, the risks to this technology are much greater, and a judgement is required as to the comparative benefits of breaking the soil or achieving the earliest possible planting. Where pre-planting cultivation is not possible, then post planting inter row cultivation which penetrates deeper than the surface crust can increase water penetration and raise yields.

**Slowing Down Water Movement**

By slowing the speed at which water moves across the surface of the soil it is possible to increase the amount which sinks into the root zone. There are three common ways of achieving this. They are:

(a) making ridges with or without ties across the contour. Ridging and tying are an accepted practice on many soils in northern Nigeria. Elsewhere there have been low levels of adoption. There are two possible reasons for this. The first is that in Nigeria where the practice is common there are high
levels of population density, and a need to increase yields per unit area of land. In more land plentiful areas where labour is at a premium the technology may place too severe a limitation on farm size to appeal to farmers. Evidence from Burkina Faso, where the yield enhancing benefits of the technology have been demonstrated and extended for some years, is of considerable farmer resistance to adoption. In other situations where soils have particularly low levels of permeability, and rainfall comes in heavy storms, then tied ridges can lead to waterlogging and yield loss. An assessment of the viability of this technology needs to be made for individual situations against the background of these constraints;

(b) through the use of surface mulches. Layers of dead plant material placed across the contour provide an effective means of increasing water penetration. Unfortunately in most of this zone plant material is either used for fodder, fuel or building materials. This is therefore an effective technology but does not provide a practical option in most of this zone where mulching material at the start of the rains (when it is needed) is in extremely short supply;

(c) placing physical barriers along the contour at intervals across the field. Stones can be used for this purpose. In more favourable rainfall areas it may prove possible to establish hedgerows of shrubs or grasses which do not seriously compete with crops, nor spread as pernicious weeds; and

(d) encouraging cereal crops which will have strong root systems capable of penetrating dense soil and opening it up for better water penetration. This involves the use of vigorous varieties (which may also have lower grain yields than smaller plants) large seeds to ensure good early establishment (an essential feature for successful new introductions) and supplementary nutrients to encourage growth. Small, weak plants on a dense soil will not only be prone to drought, but will bring about little improvement to the soil for future crops. Good seed of strong varieties with supplementary fertilization can bring about increased water availability for that crop and the one which follows.

Strategies for Increasing Household Security

There are a range of strategies used in the drier areas to increase household security in an uncertain environment. These include:

(a) mixed cropping to make maximum use of moisture and labour and to increase the chances of obtaining some harvest;

(b) mixing cultivars of a given species to increase the chances of part of the crop ripening;
(c) using daylight sensitive cultivars to extend the period over which a crop can be planted;

(d) using grain types with good keeping qualities so that surpluses can be stored for several seasons to cover drought years;

(e) using cultivars which can be harvested for grain in a good year or made into hay if the rains are poor; and

(f) using wide spacing so as to ensure adequate root development of individual plants to increase their ability to survive a drought.

Any initiatives to increase crop productivity in this zone need to be tailored around the need for long term security. Should a proposed new technique involve the abandonment of these traditional strategies (e.g. a close spaced, single cultivar, single crop, daylight insensitive cereal) it needs to be analysed in detail to establish its impact on household security over a number of years of widely varying rainfall.

**Experience of Bank Funded Projects with Increasing Water Availability and Household Security in the Sorghum and Millet Belt**

There has been very little Bank investment in rainfed agricultural projects in the drier areas of West Africa over the past ten years (e.g. Niger, Mali, Senegal, Burkina Faso) and there is only one example of a crop-oriented project. This is the Dosso Agricultural Development Project in Niger. There is some agricultural content in the Rural Development Fund Project in Burkina Faso. In the wetter part of this zone there have been several projects in Nigeria and the Sokoto, Kano and Bauchi Agricultural Development Projects will be used as examples in this study.

Only the Burkina RDF included a direct intervention to increase water availability. This was through the use of tractors to construct contour bunds on 20,000 ha of land. These were constructed, but insufficient attention was given to disposing of surplus water so that farmers were forced to breach them. Subsequently the project focussed on hand made stone lines where stones are available, and modified bunds with spillways elsewhere.

The other four projects could have been expected to have an indirect impact on increasing the cereal crops' ability to obtain water through the development of stronger plants resulting from fertilizer application. In the event the projects did bring about some increase in fertilizer use, although only a small percentage of that which had been anticipated.

There were no interventions proposed which were expected to specifically assist in increasing household security. There were proposals to change the practice of interplanting millet and sorghum on the Nigerian projects. This would have lowered overall production and greatly reduced household security. The proposals were not adopted by farmers.
Crop Production

The major crops of this zone are sorghum, millet, cowpea and groundnuts. The zone can be broadly divided into three categories with regard to these crops. These are:

(a) systems in which sorghum, millet and cowpeas are normally planted as a mixture. This is a major category covering large areas of northern Nigeria;

(b) systems in which sorghum is grown on more favourable soils in a village area and millet on less favourable soils, but the two cereals are not mixed; and

(c) systems in which only millet and cowpeas are grown because the climate is too dry for sorghum.

In the following sections the crops will be dealt with separately but reference will be made to the impact of the interaction of crop associations on the individual components.

Sorghum

The possibility for raising the productivity of this crop will be considered in both mixed and pure stands, and will cover planting material, field practices and the use of purchased inputs.

Planting Material

Local sorghums have been selected over many years for the following features:

(a) good seedling emergence and strong early growth;

(b) good tillering to compensate for shoot fly attack;

(c) rapid and strong root development;

(d) a long growing cycle which makes good use of limited mineral availability;

(e) photoperiod sensitivity which allows for a range of planting dates in a variable climate;

(f) grains which are resistant to insect and mold attacks; and

(g) plants which are tolerant of the parasite striga, and other pests and diseases.

The fundamental weakness of this material is the low proportion of grain produced relative to total plant weight. In consequence the nutrients and water used to develop four tons of crop only yield 800 kg of actual grain.
The other vegetative parts are not wasted and are used for animal feed, building materials and fuel. As population densities increase and the need for primary human food grows more urgent, then there will be a greater demand for grain by comparison with other products.

Plant breeders throughout this zone have spent many years working to produce varieties which will outperform the local cultivars. This has proved a formidable task and at the end of 50 years of work less than 5% of the sorghum area is planted with varieties bred by research workers.

There are two basic reasons for this failure. The first is that some of the essential positive features of local material such as plant vigour combined with strong photoperiod sensitivity and open panicles, which avoid grain molds, are inimical to high grain yields. It is consequently difficult to retain these positive features whilst bringing about a major increase in the proportion of grain in the total plant weight. The second reason for the failure is that research has not always been geared to actual farmers conditions and consequently the released material has not proved acceptable. In the more arid areas the released varieties have required a cultivated seed bed and moderate levels of fertility, neither of which are a feature of most farmers fields. ICRISAT's on-farm trials between 1981-84 demonstrated that none of the released varieties were superior to local material over all of the environments over which they were tried. 40% were superior under improved growing conditions, but in 60% of cases the elite cultivars were inferior to the local material under all the ecological environments in which the trials were carried out. ICRISAT also found out that there was an average drop of 50-60% between yields of elite lines on trials carried out on research stations and trials held on farmers' fields. 6/ In Nigeria a major problem has been that the released cultivars do not fit in to mixtures with millet which dominate the drier sorghum growing areas.

This situation is slowly changing and hopefully new varieties will become available which will offer farmers improved yields and stability under their farming systems. Given the bad experiences of the past, however, it is essential that care is taken that any new release has been rigorously tested under the harsh conditions of farmers' fields over a number of varying seasons and in local crop mixtures, before it is broadly commended to farmers through an organised seed distribution scheme.

There is, however, another way in which it may prove possible for agricultural staff to improve on the stability of farmers' production. This is through the movement of well proven local cultivars across ecological zones at times of significant climatic change. Farmers naturally plant a range of cultivars suited to their rainfall pattern. If after a long period (say 20 years) the pattern changes (as it did in the 1970's) then the farmers' cultivars become inappropriate. It may then prove beneficial to

6/ Appropriate technologies for farmers in semi-arid West Africa, Ohm and Nagy, pp. 166 and 162.
move local material from a traditionally drier area into the newly dry zone. Such material may be basically lower yielding and will risk being seriously damaged by molds if the weather turns wetter again, but it will provide real advantages if there are a series of drier years.

This strategy cannot be built around formal seed schemes, which cannot supply sufficient seed for a large community faced with an abnormally dry season. What is needed is a staff with a detailed knowledge of the qualities of local sorghums across a series of rainfall zones, and discretionary funds to purchase large quantities of grain from one zone to move to another when a change of weather patterns has made itself felt. If there is ongoing evidence of a period of unusually erratic rainfall in an area it would help farmers to increase their stability of production if they were given a wider range of cultivars in their home stores from which to choose according to when the rains began in any given season. In many ways this is a more demanding strategy than just multiplying and distributing a released cultivar from a research station, but for many farmers it is at present the most likely method of helping them to counteract major fluctuations in rainfall.

When sorghum is grown with millet it is essential that it be photoperiod sensitive as its planting date is determined by the millet and cannot be adjusted to a particular number of days required from planting to harvest. Photoperiod sensitive varieties flower in response to daylight length and so will mature at the same time despite differences in planting date from one season to another. In this way a later planted crop in one season will still flower before the rains finish in a "normal" year, whilst an early planted crop will not ripen until after the rains are over.

With any attempt to assist farmers improve their levels and stability of sorghum production through a change in planting material the problem of striga must be considered. With declining fallow periods this parasite is spreading across this zone. In densely populated areas it can be a major constraint on improving sorghum production. There is no available "cure" for the pest apart from long periods of cultivation with non-susceptible crops or fallowing, neither of which are practicable for many farmers. Growing tolerant varieties is the only answer at present, and a move to non-tolerant "improved" material could prove damaging to farmers in areas of serious striga challenge.

Field Practices

Three field practices can influence production. These are:

(a) land preparation;

(b) date of planting; and

(c) plant populations.
Land Preparation

In the drier parts of this zone there is no digging or ploughing prior to planting. In the moister areas, particularly in Nigeria, land is cultivated and ridged before planting. The problems of land preparation have been covered on page 46. There is quite a strong interaction between land preparation and choice of variety. Research results show that 'improved' varieties will usually only outperform local material if land is cultivated. Local varieties show little response to pre-planting cultivation. If farmers wish to switch to a more intensive system of production using fertilizer and 'improved' seed than they will also have to cultivate if they wish to obtain the benefit of these inputs. This substantially limits the adoption of 'improved' varieties. If farmers intend to use local cultivars which have been selected under zero tillage conditions they are unlikely to obtain a yield increase commensurate with the effort involved in pre-planting cultivation.

Date of Planting

The planting date of sorghum depends in part on whether the crop is being grown in combination with early millet or being planted by itself. If it is being grown with millet then the planting date is determined by that crop, which is normally planted with the first substantial rain of the growing season. This will vary widely from year to year, and it is for this reason that daylight insensitive sorghums with a specific optimum planting date are unsuitable for this combination.

Where sorghums are planted on their own, farmers will have developed a detailed knowledge of a best guess planting date in relation to the way in which the rains start. Unless a new variety with different needs is being introduced there is little scope for improving on farmers' judgement in an uncertain rainfall area.

Plant Populations

Four factors have a bearing on the choice of a suitable plant population in this zone. These are:

(a) moisture availability. In order to help secure a harvest in dry years plant populations need to be adjusted to allow adequate root growth by individual plants. Increasing plant density can lead to greater yields in wetter years and crop failure in drought seasons. Any recommendation to change plant populations needs to be reviewed in this light;

(b) nutrient availability. If a given area of soil can only supply limited nutrients (adequate, say, for 2.5 tons of crop growth which would produce 500 kg grain) then an increase in the number of plants grown could lead to an increase in vegetative output and or seedless heads which would result in a decline in grain yield. Changes in nutrient status can provide a reason for changing plant populations;
(c) the cultivar being grown. A switch from a tall traditional cultivar to a short strawed variety should be accompanied by an increase in plant populations; and

(d) the mixture in which the crop is being grown. If sorghum is to be undersown with cowpeas (which is a high value crop) then sorghum spacing has to be arranged so as to allow adequate light to reach the cowpeas.

Given the range of factors involved in deciding on the optimum plant population in any given field, any generalised recommendations on spacing for a zone should be treated with great caution. An analysis of ICRISAT's trials in Burkina comparing research recommendations and farmer practice with regard to planting arrangement found no significant difference in yield between them.

Farmers do however face problems in obtaining the stand which they want in the harsh conditions under which the crop is often grown. Seriously panned soils often need the combined energy of 8 to 10 seeds to crack the soil open and enable the plants to emerge. This accounts for the high seed rate per stand in many areas. Pests, drought, driven sand and rodents all have their impact on plant establishment. A good extension worker can join with farmers to analyse the reasons for plant loss and assist in developing strategies (seed dressing, rodenticides) to help achieve the population for which the farmer is aiming.

Purchased Inputs

Two purchased inputs have been made available to farmers for their sorghum crop. These are fertilizer and seed dressing.

Fertilizer. Many soils in this zone are poor in plant nutrients and yields are often limited by this factor. Animal manure is widely used but the number of animals is itself limited by the availability of grazing. In consequence there is inadequate manure to provide sufficient nutrients for all the cropped area. Efficient recycling of plant residues through animals can help maintain yields, but a significant increase in output can only come from an addition of nutrients to the system. Fertilizer provides one way of breaking out of a cycle of low productivity. Unfortunately because traditional sorghums have such a low proportion of their total plant weight in grain there is usually a fairly low response ratio of grain to nutrients from these cultivars. At the same time the uncertain climate leads farmers to expect a high return to any investment which they make because of the high levels of risk involved.

Responses of traditional sorghums to fertilizer will vary considerably from place to place. There are situations in which phosphorus in the soil is so deficient that yields are extremely low, and substantial increases can be achieved by the application of phosphatic fertilizer. In general, however, responses are modest, and over a large number of farms a response of 4 to 6 kg of sorghum grain per kg of N, in the presence of adequate P and K, would be a typical average. A review of the thousands of
FAO fertilizer trials carried out in West Africa cites the responses to sorghum as being 5-10 kg of grain per kg of N under trial conditions. This is also in line with ICRISAT's experience and in its Research Bulletin No. 8 (page 36) it gives a figure of 5 kg of sorghum per kg of N for traditional long strawed varieties. At current undistorted prices such responses will not give farmers an attractive return to their investment, and the use of fertilizer only provides an attractive technology if there are local distortions in input and output prices which favor the farmer, or if there are such serious deficiencies of phosphate that yields in its absence are negligible.

Seed Dressing. Seed dressing fulfills two functions. The first is to discourage rodents, insects and birds from eating the seed. The second is to control seed borne fungi which can affect the new plant's grain production. Farmers are most concerned with its first function, as serious outbreaks of fungal diseases are irregular in their occurrence and are not associated by farmers with the seed they planted. Unfortunately the most effective seed dressing for the first purpose has high levels of mammalian toxicity and is therefore being discouraged. Replacement chemicals are not as effective in preventing seed eaters but do reduce seed borne fungal diseases, and the return to the small investment involved can be considerable in years when such diseases are widespread as a result of climatic factors, and these pay for those seasons when diseases are insignificant. It is not realistic to predict specific returns to the use of seed dressing but it is a worthwhile technology to encourage and can in some years provide significant benefits.

Experience of Bank Funded Projects with Sorghum in the Sorghum and Millet Belt

Four of the five projects under review were expected to influence sorghum production through the use of a change in variety, field practices and the use of inputs. Details of these are given under headings relating to the activity.

Change in Variety

All of the projects proposed a change to "improved" varieties as a means of raising yields. In the event considerable quantities of seed were produced but there was little uptake by farmers. In Nigeria the main reason was that the varieties proposed did not fit in to the mixed farming pattern with millet. In Dosso the PCR states that the improved varieties did not yield as well as the local material under farmers' conditions.

Change in Field Practice

The principal proposal for changing field practices was an increase in plant population through the use of additional seed. The recommendations are outlined in Table 3:1.

Table 3:1 Proposals for Seed Rate Change for Sorghum

<table>
<thead>
<tr>
<th>kg/ha</th>
<th>Traditional</th>
<th>Improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bauchi</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Kano</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Sokoto</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Dosso</td>
<td>10</td>
<td>15</td>
</tr>
</tbody>
</table>

(Source: World Bank Staff Appraisal Reports).

These changes were related to a change in variety, and as this did not take place there has been no evidence of a change in plant population under the projects.

The Use of Inputs

Fertilizer. All the projects envisaged that the major impact on yields would come through a greatly increased use of fertilizer on the sorghum crop. Despite a subsidy of the order of 80% on fertilizer in Nigeria none of the projects achieved incremental fertilizer sales of the order of magnitude that had been planned. This was a result of difficulties with timely procurement, distribution and erratic rainfall. The Dosso project did not record any incremental sales. The PCR cites poor responses to the recommended applications as the primary reason for this. Fertilizer can undoubtedly play an important role in raising the production of sorghum in this zone, but the poor financial and economic returns which it offers limits the capacity of governments and farmers to expand its use.

Seed Dressing. All the projects recommended the use of seed dressing, and where there has been a regular and timely supply combined with some extension this input has been taken up by farmers.

Millet

This crop is more tolerant of drought than sorghum, and is grown on soils and in climatic zones in which sorghum will not produce. In Nigeria, it is also widely grown in mixtures with sorghum in order to increase both the total production of an area and the security of production, because of its earliness and hardiness. There are an estimated 14 million ha of millet in this zone making it the third most widely grown crop in SSA.
Possibilities for raising the productivity of this crop, whilst maintaining inter-seasonal yield stability will be considered under the headings of planting material, field practices and the use of purchased inputs.

**Planting Material**

Millet in the Sahelian zone has to be capable of:

(a) germinating at high soil temperatures;
(b) germinating in badly panned soil;
(c) resisting sand blasting in the seedling stage;
(d) yielding grain at low levels of soil fertility;
(e) resisting downy mildew; and
(f) tolerating shoot fly and striga.

Breeders have found it difficult to produce new, high yielding material which embodies all of these attributes. Among 3,000 entries screened by ICRISAT in Burkina Faso only 5 were advanced to on-farm tests but none proved superior under farmer conditions. In Nigeria selection amongst local cultivars led to the release of material under the name Ex Bornu which outyielded unselected material. Because millet reproduces by outcrossing between plants it is necessary to continue the selection process in order to maintain this superiority. This has not been carried out with sufficient rigour in recent years and much of the Ex Bornu which has been sold has little superiority to farmers own selections. In Senegal two releases IBV 8001 and 8004 have gained some popularity with farmers, but over the region as a whole a negligible proportion of the crop is planted to research station releases.

Research continues and with increasing awareness of farmers' constraints it should come up with material with increased pest and disease resistance and with a higher grain index. In considering the popularisation of such material it will be necessary to have in mind the need to:

(a) be assured of its performance under zero cultivation and poor soil conditions;
(b) attempt to encourage a number of neighbouring farmers to adopt the material together so as to slow down the dilution impact of outcrossing; and
(c) ensure that the material is not so uniform as to undermine the farmers' requirement for a range of cultivars in his crop to ensure some stability of production between widely differing climatic seasons.
Field Practices

Millet is widely grown on land which is not cultivated prior to planting and farmers therefore are able to plant with the first rain which they believe to be a part of the main rainy season. It is usually difficult to improve on this practice. Plant populations are geared to experience with water and nutrient availability over a number of years and to the needs of companion crops. Only if one of these factors is being considerably changed is there likely to be a significant long-term advantage to be gained from changing planting patterns derived from years of local experience.

Purchased Inputs

Fertilizer is the only purchased input which has been used on any scale for this crop. Because it has a grain index even lower than sorghum (16%) traditional millets give lower responses to fertilizer as a general rule. The steep section of the response curve to N is short, so that increasing applications beyond 30-40 kg N per ha often leads to lowered responses to any incremental fertilizer. Because millet is grown in poor areas where other crops will not survive there are cases where it faces serious deficiencies in P, and in these situations considerable improvements in yield can be obtained from modest applications of phosphatic fertilizer. As a general rule in assessing the impact of nitrogenous fertilizer on millet yields for large numbers of farmers in a typically harsh growing environment, and in the presence of adequate P, a yield increment of between 3 and 6 kg of grain per kg of N would apply to a range of situations. This is too low a response to provide farmers with an adequate return in the absence of a substantial distortion from prevailing international prices for fertilizer and grain.

Experience of Bank Funded Projects with Millet in the Sorghum and Millet Belt

Four of the five projects under review were expected to have an impact on millet production through the use of new varieties, changed field practices and the use of purchased inputs. Details of these are given under headings relating to the activities.

Change in Variety

Four of the projects proposed a change to "improved" varieties as a means of raising yields. In the event the overall achievement was about 2% of the SAR targets. There were two main reasons for this. The first was the problems faced by the projects in producing the "improved" seed on an annual basis in large quantities with suitable selection and isolation. The second was that the seed which was produced was not sufficiently different from farmers' own material to elicit farmer interest. It does not appear that conditions are yet ready for a major attempt to change the millet variety on the millions of ha of the crop in northern Nigeria.
Change in Field Practice

The Dosso project proposed a 50% increase in the plant population for millet, which was not adopted by farmers. On the Nigerian projects it was proposed that millet no longer be grown interplanted with sorghum, which is the current practice. Because of the advantages of both production and security that derive from the sorghum and millet mixture farmers did not follow this proposal and the projects have not affected field practices.

The Use of Purchased Inputs

All four projects anticipated that the major impact on yield would be through the use of fertilizer on millet. Despite a subsidy of the order of 80% on fertilizer in Nigeria none of the projects achieved incremental fertilizer sales of the order of magnitude that had been planned. This was a result of difficulties with timely procurement, distribution and erratic rainfall. Dosso did not record any incremental sales of fertilizer. Fertilizer can undoubtedly play an important role in raising the production of millet in this zone, but the low response ratios in many areas provide poor economic and financial returns and this limits the ability of both governments and farmers to expand its use.

Cowpeas

Cowpeas are the most important of legume crops grown in SSA in terms of area under the crop. There are an estimated 6 million ha in Western Africa, much of it in the sorghum/millet zone. Most cowpeas are grown in mixtures with other crops, usually sorghum and millet. Cowpeas are largely treated as a dual purpose crop in this zone, producing hay of high value and seeds and leaves for human consumption. In years of poor rainfall, when stock feed is in short supply and grain yields are low, the value of hay can be greater than the value of the seeds. This dual purpose crop for mixed stand cultivation has not received a lot of attention from research workers and there is limited technology available for its improvement at present. The dominant limiting factor on seed yields is insect pests, of which flower eating thrips are often the most important, but pod borers can also severely reduce yields. In store the crop is highly susceptible to spoiling by bruchids. Research has focussed on producing resistance to these pests. Some progress has been made with bruchids but there has been no real breakthrough with thrips or pod borers. There has also been considerable work on insecticidal spraying, but this applies to crops in pure stand and cannot at present be applied to the overwhelming majority of the cropped area in the region.

Possibilities for improving the production of the crop will be considered under the headings of planting material, field practices and purchased inputs.
Planting Material

There has been a major research initiative on producing varieties of cowpeas suitable for use in pure stand with insecticidal control. This material has not been developed for mainstream farmers in this zone and in Nigeria there are at present no research data available on the performance of these varieties under mixed crop conditions. Many of these are single purpose types, producing grain rather than hay. They are also mostly determinate (producing their flowers at one time) and photoperiod insensitive. Consequently they are ill suited to the current farming system.

FSU/SAFGRAD in Burkina Faso has carried out a range of experiments with mixed millet and cowpea crops over several seasons. They used the IITA release recommended for this zone (TVX 3236). This was consistently outyielded by local cultivars. The report on this whole series of experiments summarises the findings as follows: "The climatic constraints and variabilities in the central plateau of Burkina and in many other areas of WASAT emphasize the importance of the stability of production offered by indeterminate cowpeas (local) compared to determinate varieties (improved)". 8/

IITA has now appreciated this situation and in its new statement of priorities and strategies records that a "fundamental change is required in the breeding program" 9/ and it is going to start work on cowpeas suited to the conditions of the sorghum and millet belt. It expects that it will be some years before new varieties will be available which outperform local cultivars under farmers' conditions.

What is called for is a deep rooting, dual purpose, semi-determinate, photoperiod sensitive cowpea which produces a flush of flowers after the millet harvest. This would offer farmers the opportunity to control flower thrips with one spray application until such time as the breeders are able to produce resistant material.

In summary, there is little material released from research stations which can assist farmers to increase the productivity of dual purpose cowpeas in traditional crop mixtures. Good extension staff can however look out for existing local cultivars which have advantages over others in a zone and help to move such cultivars between areas or between farmers.

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Field Practices

The main thrust of research and extension on field practices for this zone has been to induce farmers to grow the crop in pure stand rather than in mixtures with cereals. This reduces overall productivity in most situations and for small scale farmers also weakens their security of production by reducing their most dependable grain crop. For farmers with surplus land and labour, pure stand cowpeas can make quite an attractive cash crop, but this form of production is likely to involve a tiny fraction of the total area.

For the main crop in mixed stand the possibility of increasing production will be considered under the heading of time of planting, plant populations and weeding.

Time of Planting

The time of planting for mixed stand cowpeas is linked to the crops with which they are planted. Local, photoperiod sensitive cultivars have been selected on the basis of their being able to develop vegetatively during the rainy season in association with other crops, and then respond to daylight signals to mature after the rains and after the harvest of the companion crop. There are few opportunities for improving on farmers' practice with their existing material under these circumstances. Only for individuals who switch to pure stand cowpeas is there likely to be any need for suggesting a change in time of planting.

Plant Populations

Virtually no work has been done in the main growing area in Nigeria on plant populations or plant arrangements in the common sorghum and millet mixtures with cowpeas and there is consequently no information available in that country for providing farmers with recommendations for any change in their present practices. Populations also vary greatly according to the priority which the farmer puts on grain, hay or cowpea seed production, so that any recommendations for change would have to be tailored to individual goals.

In Burkina FSU/SAFGRAD have carried out a range of experiments on millet and cowpea population levels over several seasons. These were sited in an area of above average fertility and rainfall and also under typical farmer conditions of limited nutrients and water. In the experiment with unusually high fertility and moisture (millet yields 1,800 kg per ha) increased populations led to increased yields. In the typical farmer situations (millet yields 200 - 400 kg per ha) increased plant populations above the farmers normal practice led to a reduction in the returns to the
farmer. The report on this series of experiments states that under favorable conditions of water and fertility it is profitable to increase cowpea populations, but under less favorable conditions farmers present practice is more dependable and profitable. 10/

Weeding

The cowpea intercrop is usually planted after the cereal crop has been weeded and is also providing considerable shade. The local creeping cowpeas are themselves good weed suppressants once they start growing so that weeds are not usually a constraint on crop production.

Purchased Inputs.

Fertilizer. There is no research information available on the impact of fertilizer on cowpeas in mixed stand in this zone. It is possible that a basal dressing of phosphatic fertilizer would have a favorable impact on yields, but no data are available on the returns which could be expected to such treatment.

Storage Chemicals. Unlike local sorghums and millets which suffer little loss in locally built stores the cowpea crop is subject to serious insect attack. Farmers can be helped to preserve a higher proportion of their crop for consumption through the purchase of heavy duty plastic bags (to provide airtight storage which stifles the insects) or approved storage chemicals. Both of these provide practical new technology for increasing the actual availability of cowpeas to farmers.

Experience of Bank Funded Projects with Cowpeas in the Sorghum and Millet Belt

Four of the five projects under review included a component intended to increase cowpea production. All of these were expected to encourage farmers to move into growing cowpeas in pure stand using new varieties, fertilizer and regular insecticidal spraying or in new configurations with millet which allowed for spraying and fertilizer use. This was a new approach to cowpea production in all the areas covered by the projects. In the event the pure stand, sprayed cowpea package had no adoption in Dosso. In Nigeria by Year 5 there was adoption on about 10,000 ha by comparison with the 700,000 which had been planned. A great deal of effort was put into this component (two expatriate staff worked on cowpeas full time in Kano) but the projects faced the problem of promoting a system which it was found often lowered overall food and fodder production and reduced production stability.

10/ Ohm and Nagy, op cit, p. 258.
This is because a sorghum, millet, cowpea mixture in Nigeria with no chemical spraying produces the following in an 'average' rainfall year:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorghum grain</td>
<td>600</td>
</tr>
<tr>
<td>Millet grain</td>
<td>400</td>
</tr>
<tr>
<td>Cowpea seed</td>
<td>200</td>
</tr>
<tr>
<td>Stover for feed</td>
<td>2,000</td>
</tr>
</tbody>
</table>

By comparison a pure stand of sprayed cowpeas can be expected to produce 800 kg of cowpea seed, but the recommended determinate varieties defoliate and do not produce hay. There is thus a large increase in cowpea yield but not of total food and fodder production.

Small numbers of farmers with larger farms will continue to find the proposed technology attractive for a cash crop which can be planted on spare land at a time when labour is not at a premium. For the great majority of farmers the technology has not proved attractive and it is not anticipated that the major shift which these projects were expected to bring about in cowpea production will take place until new research produces material better suited to intensifying cowpea growing within the mixed crop system.

Groundnuts

Groundnuts are the only exotic food crop which has become widely established in the drier areas of West Africa. Because it is an imported crop it does not have the long history of selection and adaptation to local conditions enjoyed by the indigenous sorghums, millets and cowpeas. In consequence the research stations have a particularly important role in drawing on the wide range of genetic material available internationally in order to help farmers to obtain plants which are better adapted to the diseases and environmental stresses which limit crop production. One problem with improving groundnut production is the high seed rate in relation to the crop harvested. Under farmer conditions in areas of poor soils and erratic rainfall farmers can only expect to get back 5 to 10 times the seed which they plant. In a poor year the harvest may only be twice the weight of the planted seed. This compares with millet in which the harvest is between 100 and 200 times the weight of planted seed. The implications of this for the farmer are that seeds constitute a major investment in groundnut production and that two or three poor harvests in succession can have a dramatic impact on the area under the crop. For the development worker this factor renders it difficult to produce quantities of seed of a new variety which are adequate to have a significant impact on a large production area over a short period of time.

The major constraints limiting groundnut production in this zone are:

(a) fungal leaf diseases;

(b) virus disease;
(c) unreliable rainfall; and

(d) low nutrient availability.

Possibilities for improving production in the light of these constraints will be considered under the headings of planting material, field practices and purchased inputs.

**Planting Material**

All of the groundnuts planted in this zone are introduced and most varieties described as 'local' are earlier releases from experimental stations. The availability of improved material will be reviewed in the light of the major constraints outlined above. These are:

(a) resistance to foliar diseases. Early and late leaf spot are a major problem limiting groundnut yields. Germplasm with resistance to these fungi has been identified and hopefully new varieties will be released in the future with high levels of tolerance. At present there are no agronomically acceptable groundnut cultivars with resistance to either of these diseases;

(b) resistance to virus disease. The major virus disease in this zone is rosette and it has been a growing a problem in recent years. French scientists have done excellent work in identifying resistant material. These resistant cultivars are all long cycle groundnuts, which are well suited to the moister areas, but require too long a season to be of use to farmers in the drier parts of the zone where groundnuts are a popular cash crop. There is continuing research to identify resistance in short season groundnuts. Several releases have been made of material which was thought to be resistant, but subsequently broke down under field conditions. Rosette therefore still poses a threat to farmers in the drier areas;

(c) the problem of unreliable rainfall. A series of dry years in the semi-arid areas of West Africa have had a serious impact on groundnuts in this region. They have also focussed attention on the need to embody drought resistance into the breeding program. Hopefully this work will bear fruit in the future, but at present the main concern of the farmer and extension worker is to ensure that any new varieties have growth periods adapted to current rainfall patterns; and

(d) low nutrient availability. Research is in hand to identify groundnuts capable of making better use of soil phosphorus and fixing more nitrogen. It will be some years before such material is ready for release.
In summary the research system is well aware of the main constraints to groundnut production and is working on them. A number of improved varieties have been released and are available for different zones, but they do not as yet address the main limitations to groundnut production. In consequence the wide difference between the yields on research stations and on farmers' fields are largely attributable to the intensive use of fungicides, pesticides, fertilizer and irrigation rather than to differences in planting material.

Field Practices

Four factors influence yields per unit area of land in groundnuts. These are date of planting, plant density, weeding and crop sanitation.

Date of Planting

There is abundant evidence that early planting has a favorable impact on yields in most seasons. The constraint on the farmer which may delay planting is soil cultivation. Even in areas in which no land preparation is carried out for grain crops, there is usually a pre-planting cultivation for groundnuts. Any innovation aimed at increasing yields through earlier planting must address the labor bottleneck of land preparation. Possibilities for this include, post harvest ploughing or digging and supplementary feeding of work oxen.

Plant Density

The issue of plant populations is particularly complex with groundnuts. The factors involved include:

(a) groundnut seed is costly and close spacing reduces the output per seed planted;

(b) close spacing greatly reduces aphid activity. Aphids carry the virus disease rosette, so that close spacing can minimise the incidence of the disease;

(c) close spacing greatly increases the potential yield per unit area of land; and

(d) groundnut cultivation is often carried out on ridges. It is difficult to make ridges less than 80 cm apart. This therefore makes it impossible for farmers to achieve the close spacing (15 cm x 15 cm) necessary for aphid control and high yields per ha.

Any recommendations with regard to plant populations therefore have to be made in the light of the severity of the rosette challenge, the availability of land, the cost of seed and the farming system (ridge or flat; hand or ox powered). It can be seen that universal recommendations are not possible under these circumstances and farmers and extension staff need to address individual situations on their merit.
Weed Control

Groundnuts, being short, do not compete well with weeds. A weedy environment is also associated with increased incidence of leaf spot. Herbicides are available for use on groundnuts but are unlikely to be appropriate to the needs of farmers in this zone. They therefore need help to review their whole farming system so as to find ways of releasing labour to weed groundnuts before the crop is seriously damaged by the competition.

Crop Sanitation

Because leaf diseases are a major determinant of groundnut yields, and because the diseases are carried over in the soil and on plant debris, it is particularly important to encourage farmers to rotate their groundnuts with other crops and to ensure that the haulms are eaten by livestock or burned. This is simple technology which can produce significant benefits when farmers are not fully aware of the way in which disease is carried over and spread.

Purchased Inputs

The high yields obtained on research stations are associated with the extensive use of fungicides, aphicides and fertilizer. This demonstrates the availability of technology to raise yields. Unfortunately the relationship between costs and benefits in an uncertain climatic environment often render such inputs financially unattractive to farmers so the technology is not applicable. Each of these will be described in the following sections.

Fungicides. Leaf diseases regularly reduce yields by 50%, and they can be controlled by regular spraying with fungicides. Despite the high level of losses, the current cost of appropriate chemicals delivered to the remote areas of this zone do not make their use attractive. This is a technology that needs to be investigated in detail in any situation where there is a well established system for distributing farm inputs so as to ascertain whether local prices may allow for its adoption.

Aphicides. Aphids are the vectors of the virus disease rosette and their control reduces infection by the disease. Spraying has been the traditional means of control. Unfortunately infestation fluctuates widely depending on climatic conditions. If farmers wait until they see a major infestation it is too late to prevent the spread of rosette. If they spray every year the cost becomes unattractive. Systemic chemicals can now be used on the seeds, but they are of such high mammalian toxicity that their use by smallholders should not be encouraged.

Fertilizer. Groundnut yields can be increased through the use of phosphatic fertilizer on a number of soils in this zone. Responses are highly variable and work in Nigeria has shown a considerable reaction between the response to phosphate and the availability of calcium, potassium and boron. Samaru Research Bulletin No. 35 records that 110 out of 210 trials gave significant responses to superphosphate. In the wetter areas the response was 6 kg of
nuts per kg of P and in the drier areas it was 1.3 kg. Research trials using fertilizer often include disease control which can enhance the impact of the fertilizer. Under farmer conditions, with moisture limitation and high disease pressure, results from the use of phosphate can vary between no yield enhancement and 6 to 10 kg of nuts per kg of P. Making fertilizer recommendations under these circumstances requires more detailed knowledge of local soil and crop conditions than is the case with nitrogen application to cereals, to which there is usually a positive response.

Seed Dressing. Groundnut seed is expensive and the comparatively small cost of seed dressing to give protection against fungal and insect attack and improve plant establishment can give worthwhile albeit unspectacular returns.

Summary on Groundnuts

This is a crop for which there is a wide disparity between research results and farmer performance. One of the reasons for this is the role that disease plays in yields. In the absence of resistant cultivars and appropriate chemicals at attractive prices farmers yields are inevitably much lower than on research plots with disease control. A second reason is that research yields are expressed in terms of output per unit area whereas farmers are often more interested in output per seed planted, so that comparisons are often made between two quite differing situations.

Groundnuts do offer the promise of gains in output as a result of new technology and it is possible that there will be more appropriate solutions to farmers constraints over the next few years which will enable those gains to be made.

Experience of Bank Funded Projects with Groundnuts in the Sorghum and Millet Belt

Four of the five projects being considered in this section contained plans for increasing groundnut yields per ha. These expected to bring about the increases through the use of new varieties, changes in plant population and the use of fertilizer. One project proposed the use of insecticidal sprays.

Changing Varieties

The groundnut improvement strategy was based on a change to new varietal releases from the research stations, the seed of which was to be multiplied and distributed by the projects. In the event none of the projects achieved a small fraction of their targets. There were two basic reasons for this. The first concerned the difficulty of producing large quantities of improved seed for a crop with a multiplication ratio of around 14 to 1 under moderate management. The second was the identification of varieties which were perceived by farmers as being superior to their existing material. Project staff in Nigeria decided at an early stage that they could not identify material which was sufficiently better than farmers' own
varieties to elicit demand for seed at above market prices, and this component was not therefore implemented. When a truly rosette resistant variety is identified for the drier areas, which is also acceptable in other respects, then this situation may change.

Changes in Plant Populations

Three of the projects recommended the use of increased seed rates as a means of increasing yields per unit area of land. Because of the shortage of seed in the area, resulting from a combination of dry years and rosette attacks, farmers were not prepared to increase the seed rate per unit area of land, and the projects' recommendations were not accepted.

The Use of Purchased Inputs

All four of the projects recommended the use of phosphatic fertilizer on the area under improved groundnuts. Recommendations varied between 16 and 64 kg of P per ha but it is only possible to deduce the anticipated response ratio for Dosso where it was expected to be 4.35 kg of nuts per kg of P.

As with the use of fertilizer on other crops none of the projects achieved more than a small fraction of the incremental sales which had been anticipated. In Nigeria the supplies of single superphosphate were erratic and of poor quality. It was a period which included several seasons of severe rosette disease which drastically reduced yields and acted as a disincentive to farmers to purchase fertilizer.

The Kano project proposed the use of insecticide to control aphids. This strategy was followed by a few progressive farmers, but the wide variation in severity of attack between seasons and the critical timing of spraying, if it is to prevent rosette, acted as a disincentive to the widespread adoption of this practice.

Summary

These projects did not succeed in their objective of raising groundnut yields per unit area of land. This does not mean that there is no viable technology for increasing the productivity of groundnuts, but it does highlight the need for particularly careful assessment of the technology. Specifically this includes:

(a) availability of new varieties with such outstanding advantages that farmers will pay realistic prices for seed;

(b) a well designed mechanism for bulking seed of a crop with a low reproductive ratio and high labour demand; and

(c) adequate knowledge of local soil conditions which will allow for accurate prescriptions for a financially attractive fertilizer recommendation.
4. THE SAVANNAH ZONE OF EASTERN AND SOUTHERN AFRICA

Background

This is a large and varied zone which in a more detailed work would be divided into several separate sections. This paper will attempt to give some indicators as to available and applicable technology but these will not be appropriate to the whole area. Savannah is found in the central plains of the Sudan, parts of Ethiopia and Somalia, and in the lower elevations of east and central Africa. As a broad generalisation it can be said that the main constraints facing crop farmers in this zone are erratic rainfall and severe labour bottlenecks. Rainfall is bimodal in a number of areas, so that although total annual precipitation may be adequate to produce good crop yields, its division into two more or less separate seasons greatly reduces its usefulness. Much of this zone is not yet densely populated so that land is not often a major limitation to production.

Farmers have adopted a number of strategies to offset the constraints imposed by the problems of rainfall and seasonal labour shortage. These include:

(a) staggered planting over several weeks so that at least one portion of the crop will receive adequate moisture at critical points in its development;

(b) switching between more and less drought tolerant crops according to how the season develops;

(c) dry planting of seed before the rains start so as to obtain the maximum length of growing season; and

(d) using oxen and tractors to extend the area under cultivation.

These strategies enable farmers to produce low but moderately consistent yields from farms which are usually considerably larger than those in the neighbouring highlands, thereby compensating for low yields with extensive crop areas. Under such conditions weeding frequently becomes a major bottleneck and a significant factor in determining yields.

The Availability of Technology to Overcome Erratic Rainfall and Labour Bottlenecks

There are two lines of approach to assisting farmers overcome the problems of erratic rainfall. The first is the production of plant types which are either capable of withstanding considerable periods of drought such as are common in weakly bimodal weather systems, or are quicker maturing than traditional cultivars. These will be considered under the individual crops. The second is to increase the proportion of rainfall that actually becomes available to plants.
The techniques available to farmers for increasing the availability of water to their crops are described on pages 45 to 47. There are some differences in soils and climate. There is more pre-planting cultivation in this zone than in the drier parts of the West African sorghum zone. There is little ridging and the practice of tied ridging has not been accepted on any significant scale in any area. The use of live barriers (grass or bushes) across the contour is not applicable in areas in which land is periodically fallowed under grass which is then subject to annual burning. In those areas in which either fallowing or burning do not occur then such barriers could be of help in slowing run-off. In dry stony areas the use of stone barriers along the contour could be used even in areas subject to fallow and fire.

Water harvesting, to capture rainwater from an unplanted area and guide it to crops, is practised by a few farmers (e.g. the rice growers of Sukumaland in Tanzania) but it is a technology which is in its infancy in this zone. Increasing attention is being given to ways of developing water harvesting methods which fit into particular farming patterns. Out of this should come applicable technologies for increasing crop production in drier areas, which will provide farmers with a new tool for overcoming the constraint imposed by erratic rainfall.

There are two major labour bottlenecks which face most farmers throughout this zone. The first is at the time of land preparation and the second is when weeding would have the most impact on yields. Technical options exist for overcoming both these bottlenecks but their viability varies greatly from place to place. These options can be broadly divided into those involving mechanisation and those involving purchased inputs.

**Mechanisation**

Three technologies have been used in various parts of this zone to overcome labour constraints at the time of cultivation and weeding. These are:

(a) the use of tractors. This option has received a great deal of attention and investment. Government sponsored tractor hire units have been tried in most countries covered by this zone. Their experience has been consistent with that in other areas in that they have required heavy subsidies and covered only a small fraction of the farming area. Private tractor ownership has been successful in several areas (e.g. the central plains of the Sudan and Shinyanga in Tanzania). There are three features which have typified these successful initiatives. The first is fertile soils capable of producing a number of crops without a long fallow. The second is an open treeless plain involving little or no land clearing. The third is the possibility of using the equipment in several different areas with varying rainfall patterns, so enabling owners to have long operating seasons. The success in Shinyanga was brought to an end when the government forbade tractor owners to work outside their own village area, thereby
limiting the utilisation of the equipment. In areas with poorer soils, heavy tree cover or limited opportunities for alternative work outside a narrow cultivating season, tractor owners face the same problems as those outlined in pages 22 and 23. There are declining opportunities for assisting local farmers to use tractors profitably in the absence of subsidies because the terms of trade have moved against the agricultural sector in a number of countries. In the Sudan mechanised farming continues on a large scale, but there is increasing concern about its impact on soils, as profit margins are squeezed and machinery owners attempt to cut costs through the use of practices which undermine long-term viability. For most farmers in the zone tractors constitute an available but non-viable technology;

(b) the use of ox-powered cultivation. There are a number of places in this zone in which ox-cultivation is the dominant form of land preparation (e.g. N.E. Uganda, Sukumaland in Tanzania, S. Zambia, the drier parts of Zimbabwe). The common factors in these areas are people with a long history of cattle keeping, soils which are comparatively easy to work and moderately open country with few large forest trees. There are other areas which appear to embody similar features in which there has been no, or very little, such development (e.g. the plains of the S. Sudan, the drier areas of Kenya, the Bay region of Somalia). Two factors may be responsible for this. The first is that farmers do not see cultivation as a bottleneck because they direct seed into untilled ground. The second concerns the relationship between men and cattle amongst some Nilotic tribes which precludes the use of animals for "menial" work. Both of these factors deserve attention before any projects are initiated to introduce widespread ox cultivation in such areas; and

(c) the use of ox-powered weeding. There is considerable scope for increasing ox-powered weeding in many areas within this zone. It is only well developed in Zambia and Zimbabwe where, on many farms, it completely replaces hand weeding. It has potential under two different circumstances. The first is that in which ox ploughing has been well established for many years, but in which farmers have never progressed to ox weeding. Under these circumstances there is a need to demonstrate the benefits of more accurate planting and better animal training which are required for weeding. This is an area in which technical assistance in the form of skilled smallholder farmers could prove most valuable. This would involve bringing farmers from areas with a long tradition of ox weeding to areas where it is unknown, so that farmers can see in practice that this is a replicable technology. This would require little money (by comparison with international consultants) but good human skills in selection of the right demonstrators and the organisation of their use. The second situation is that in which no cultivation is carried out but
in which weeding is a critical constraint. The need here is for the introduction of a simple tool bar with a single tine for making straight furrows into which seed is hand planted, and with two additional tines for weeding. In the drier sorghum growing areas (e.g. Bay region in Somalia) this is a technology which could have a major impact on production by reducing the water loss to weeds which is often a critical factor in the survival of the sorghum.

Experience of Bank Funded Projects in Overcoming the Constraints of Erratic Rainfall and Labour Bottlenecks in the Savannah Zone of Eastern and Southern Africa

The five projects selected to represent this zone are:

- Sudan - Western Savannah Project II
- Somalia - N.W. Region ADP
- Somalia - Bay Region ADP
- Tanzania - Mwanza/Shinyanga RDP
- Tanzania - Tabora RDP

Only one project, the Somalia N.W. Region ADP had a component which was specifically designed to overcome the constraint imposed by erratic rainfall. This consisted of the use of heavy earthmoving equipment to build large bunds along the contour in order to reduce run-off. It was anticipated that this would raise yields of grain by 400-500 kg per ha. The bunds did not involve any catchment of water from outside the cropped area but did result in a redistribution of the water. The upper half of the inter-bund area showed increased run-off because the top soil had been removed to build the bund. The lower half of the bunded area had increased water. The effect of this was to reduce yields in the top half of the plot and increase them in the bottom. A detailed survey of the impact of this technology in 1987 indicated that the loss was counterbalanced by the gain to give overall yields on the bunded land which were not significantly different from those on neighbouring unbunded plots. Plans were made to gear the project towards more positive water harvesting but it was disrupted by political factors and those plans have not been put into practice.

Three of the projects had components intended to address the problems of labour constraints. These were the two Somalia and the Sudan projects. Two, Bay Region and Western Savannah, proposed funding for research into ox-drawn equipment. In the Bay Region some research was carried out but has yet to be translated into a supply of equipment. Farmers' problems have been identified and simple equipment has been designed, but the project has been unable to leap the hurdle of stimulating local production and distribution. This is particularly unfortunate in an area where the farmers' greatest constraint is early weed control and technology is available with which it could be overcome. The Western Savannah project is planning to introduce a small number of weeder/seeder into an area where some ox-drawn equipment is already in use, but where new tools could improve efficiency. A new toolbar has been designed and manufactured by local blacksmiths. The next stage, as in Bay ADP, is to move into commercial production. The same project was also expected to experiment
with new tractor drawn equipment and was to establish a small tractor hire unit to pioneer new equipment, in an area where there is widespread use of tractors with tools which some consider to be damaging to soil quality. In the event the tractor hire unit is working with conventional equipment and has not made any progress in developing less environmentally hazardous techniques for land preparation and sowing.

The Somalia N.W. project provided foreign exchange for the purchase of ox ploughs for an area where their use is already well established but supplies are constrained. The Mwanza project in Tanzania is located in an area in which ox cultivation is already widespread and no further interventions were considered necessary.

There has been an awareness in Bank planning of the need to assist farmers to overcome the labour bottleneck at weeding time through the use of ox-powered tools, but there has not yet been a successful development of widespread uptake in this zone. This is an available technology which could certainly be viable in a number of areas. Future projects could usefully pay more attention to the practical problems of stimulating the production of low cost weeders by local workshops and of transferring the technical skills of weeding with oxen through farmer exchanges between countries.

**Crop Production**

The major crops of this zone belonging to the group being covered by this study are sorghum, maize and millet. Of these sorghum is by far the most important for the zone as a whole, covering some 7.5 million ha, although in some areas within the zone it may not be the dominant crop.

**Sorghum**

Three factors differentiate the sorghum growing of this zone from that of West Africa. The first is that little of the crop is interplanted with millet. The second is that in areas of short, monomodal rainy seasons farmers have selected relatively short stemmed, tight headed cultivars with higher grain indices than the tall varieties. The third is that birds are often a much more serious problem in this zone and play a significant role in decisions regarding the cultivation of the crop. The availability of technical innovations will be considered under the headings of planting material, field practices and purchased inputs.

**Planting Material**

Farmers have selected an enormous variety of sorghums to match a range of growing conditions and food preferences. In Sukumaland in Tanzania 109 named cultivars in common use have been identified by the agricultural staff, and for the zone as a whole the number would be in the thousands. A concerted effort to produce improved varieties was started in the 1940's. In the Sudan the focus was on the needs of mechanised farming, and resulted in the release of a local cross called Dabar which is still in use. In East Africa work was concentrated on limiting bird damage, which was seen as the
major constraint on production. Little progress was made in this respect over existing material. Subsequently the East African program turned its attention to yield, rather than bird damage, and this work produced the varieties Serena and Seredo which have gained some popularity. They are quick maturing and high yielding but the grain quality and storage properties are poor. The grain can be used for brewing for some three months following the harvest, after which there is serious deterioration. It cannot replace the hard endosperm cultivars used for food which have to be stored from one season to another. There are now breeding programs in most countries in this zone, a number of which are assisted by ICRISAT. Two groups have made progress with this crop in the recent past:

(a) in the Sudan (the largest sorghum producer in the zone) the focus has been on hybrid material. A hybrid, Hagaeen-Durra-I, has been released. Although one of its parents (Texas 623) contains material from the Sudan, the hybrid does not have resistance to striga which is a major problem in many areas. At present it is envisaged that this hybrid will be of most use to farmers with access to irrigation and moderate levels of soil fertility. It will also provide experience with the production and distribution of hybrid seed. This will be of use when material becomes available which embodies more of the characteristics required for the large number of farmers who plant under harsh production conditions with a striga problem;

(b) Zimbabwe and Zambia, where the focus has been on the production of both varieties and hybrids. Because the main striga species in southern Africa is asiatica, the plant breeders have been able to make direct use of Indian material (which is not the case elsewhere in Africa). In Zimbabwe this has led to the release of ZVI which has considerable promise, whilst in Zambia there are some useful hybrids in the pipeline. There is a new focus in this region on sorghum for brewing and for animal feed.

In summary, there has been considerable research on sorghum breeding in the past but to date this has resulted in less than 10% of the sorghum area being planted to research station releases. Fresh initiatives will hopefully result in greater impact in the future, though much of this is likely to be in the more favoured areas for some time to come. In the case of hybrid material, the production and distribution of large quantities of seeds to remote, poor areas will pose a major challenge. In reviewing any new sorghum variety to assess its suitability as a technical innovation particular attention should be paid to:

(a) its tolerance to bird damage;

(b) its tolerance of local striga species;

(c) its tolerance of farm level growing conditions; and

(d) its suitability to the purpose for which the crop is grown and the preferences of local people.
Field Practices

For the majority of farmers in this zone the factors involved in land preparation, date of planting and plant populations are the same as those outlined on pages 52 and 53. The exception to this is the mechanised large scale farming of the Sudan. This is a highly specialised situation and the technical and soil conservation issues involved do not belong to a general survey of this nature.

Purchased Inputs

The two purchased inputs available to improve on farmers' sorghum yields are seed dressing and fertilizer. Seed dressing can have a noticeable impact in seasons or areas with substantial seed borne disease problems. More often the impact is modest, but because of the low cost and low labour input required it is a technology worth encouraging. It is not possible to give generalised figures on likely returns to seed dressing in terms of increased grain per kg of dressed seed.

There has been little use of fertilizer by farmers on the sorghum crop in this zone, and little experience of its impact at the farmer level. On the Qoz sands of the Sudan there have been substantial responses to phosphatic fertilizer. These represent the application of a fertilizer to offset a specific deficiency which is severely limiting plant growth, rather than as a means of generally improving soil fertility. Crop responses are likely to vary greatly according to the severity of the deficiency. In those areas in which tall, long season sorghums with a low grain index are grown, the response ratios to fertilizer are likely to be similar to those described on page 53 and are unlikely to provide attractive returns to farmers at undistorted prices. When high yielding shorter strawed hybrids and varieties are available to farmers, then response ratios nearer to those given by maize could be obtained in more favorable climatic areas. This technology is likely to have a limited impact for some years to come in the remote, harsh environments which typify much of the sorghum growing area of this zone.

The Experience of Bank Funded Projects with Sorghum in the Savannah Zone of Eastern and Southern Africa

Three of the five projects under review in this section made proposals for raising sorghum yields through the use of improved field practices or the use of new seed or purchased inputs.

One project (Somalia - Bay Region) provided funds for research which it expected to produce new extension messages which would lead to yield increases from a base of 375 kg per ha to 675 kg per ha. It also expected widespread adoption of ox-powered tillage which would raise yields. In the event the research program has not so far identified sorghum varieties suitable for release which outperform local material, but work still continues. There are indications that P may give a strong response on certain soils but this has yet to be confirmed on a widespread farm level
basis. The project has not therefore been able to initiate the yield increases that were anticipated.

Both of the Tanzanian projects expected to bring about yield increases through the use of improved seed. The change in variety was expected to raise yields from 425 kg per ha to 520 kg per ha. Seed multiplication on a large scale proved a major problem and this strategy was not significantly tested. The projects also proposed the use of seed dressing. This was expected to raise yields by 90 kg per ha on average once in three years when smut was a problem. Seed dressing has gained in popularity but supplies are erratic. Only the Tabora project proposed the use of fertilizer on sorghum. The application was to be of 31N and 11P per ha. In the event farmers did not allocate fertilizer to sorghum but used it on higher value crops.

In summary the Bank's experience with raising sorghum yields in this zone has not been encouraging so far. Hopefully new varieties in the research stations will offer sufficient yield increments to attract both farmers and private seed producers, and so provide future opportunities for more worthwhile initiatives. Changes in plant populations and planting dates of traditional material offer less scope for striking change, and fertilizer is only likely to offer attractive returns in exceptional circumstances.

Maize

This crop is not well suited to considerable parts of this zone because of its susceptibility to water stress. Despite that fact an increasing area is being allocated to maize. One reason for this is because the advent of widespread primary education has created problems with regard to bird scaring for sorghum, and maize is not subject to bird attack. A second reason is a growing preference for the quality of maize flour as compared to sorghum.

There is technology available to increase maize yields, but in areas of erratic rainfall it is water stress which is often the ultimate determinant of productivity. This is not only because of the immediate impact of drought on the plant, but because farmers in such uncertain areas limit other investments into the crop. The uncertainty over the possibility of harvesting a reasonable crop of maize leads farmers to mix maize with a number of other crops which results in lowered maize yields but increases security and may also increase total production. This paper will focus on situations in which maize is the dominant crop in a mixture or is grown in pure stand. It will consider the available technology for improving productivity under the headings of planting material, field practices and purchased inputs.

Planting Material

In the drier areas which characterise much of this zone the main need of farmers is for a variety which can deal with erratic rainfall and drought. Plant breeders have been successful in producing quick maturing varieties (e.g. Katumani composite) which are described as drought avoiding. That is to say that they can mature in a short rainy season. Unfortunately
they tend to be particularly sensitive to moisture stress in their growing period. Many areas in this zone in which the rainfall is low also suffer from erratic distribution. In consequence these quick maturing but drought sensitive varieties are not particularly useful and have not gained widespread acceptance. What is needed are varieties which are drought tolerant, particularly at the time of tasseling. Under conditions of water stress, pollen shed and silk emergence do not coincide. Silking is delayed and in consequence there is little pollen available to fertilize the ova, which results in poor seed set. CIMMYT is selecting material in which pollen shed and silking are synchronised under conditions of water stress, but it will be some time before any varieties are released to farmers which embody this characteristic, and are in other respects drought resistant. There is therefore little planting material that can be offered to farmers in areas of low and erratic rainfall which will be superior to their existing selections.

In areas with more dependable rainfall the research stations have released a range of improved material. These include the composites from Ukiriguru and Ilonga in Tanzania, the quick maturing hybrids in Zimbabwe and the heat tolerant X105A hybrid in Kenya. There has been varying success in popularising this material. In all of the zone only a small portion of the hotter, savannah areas is planted to improved material. This is partly a supply problem, but also reflects the other constraints on yield improvement faced by farmers which limit the increases which can be achieved through a change in planting material. Only as these other constraints are overcome will many farmers find it worthwhile investing in improved seed.

In summary, there is little scope for improvement in planting material in areas subject to erratic rainfall and mid-season drought. There is a range of material available in areas of higher and more dependable rainfall for farmers who are able to provide the quality of management which will allow the genetic potential of such material to be manifested.

Field Practices

Date of planting, plant populations and weeding are the three factors which have the most influence on maize yields.

Planting early in the rainy season has a major impact on yields (see page 34). Farmers are mostly aware of this fact but face two constraints in achieving this goal. The first is a severe labour constraint for the first half of the rainy season when land preparation, planting and weeding all compete for a farm family's labour resources. In consequence it is seldom possible for a family to plant more than a small part of their crop at the optimum time. Research has paid little attention to this situation and extension staff can often only suggest that the farmer achieve the impossible, or drastically reduce his or her farm size and so cut down on household security and total output. What farmers need in order to improve their total output is:

(a) the identification of maize varieties which are more tolerant of late planting to provide the farmer with a succession of better adapted planting material;
(b) the identification of cropping patterns which provide an opportunity for land preparation early in the dry season;

(c) the identification of planting methods (e.g. in the furrows of old uncultivated ridges) which then combine actual cultivation with first weeding;

(d) the identification of spacing and fertilizer recommendations for late planted maize; and

(e) the introduction of a single tine for opening a planting row with oxen. Ox-drawn weeding and inter-row cultivation would then replace pre-planting ploughing.

All of these would involve extension staff in more work than the present practice of exhorting the farmer to plant early. Without such help to add to their own ingenuity there will continue to be serious losses in yield resulting from the farmer's inability to plant at the optimum time.

The second constraint occurs in areas with partially bimodal rainfall with a weak trough in-between the two peaks. If farmers plant at the beginning of the first rains they may completely lose their crop in the between season dip. If they wait until after the dip there may be too short a season in which to mature a crop. In Sukumaland in Tanzania the research/extension recommendation is to plant maize in mid-January. Farmers universally plant in October and November. If this crop dies in the December dip they plant sorghum in January because of its greater drought tolerance, whilst if January planted maize runs out of moisture in March it is too late to replace it with another crop. The research advice produces a higher proportion of successful maize crops, but some total crop failures. The farmers practice results in fewer successes with maize but always produces some grain harvest.

Many farmers therefore have little applicable technology available to enable them to plant their crop at the optimum time. Fresh and imaginative initiatives are required to assist farmers to meet this goal, and in many places extension staff have yet to be alerted to this need.

The situation with regard to plant populations and weeding is similar to that described on pages 35 and 36. There is more ox cultivation in this zone than in that described in section 2 above, and a greater opportunity to develop skills in using ox-drawn equipment to overcome the early weeding bottleneck.

The Use of Purchased Inputs

In the drier parts of this zone in which farmers may lose two maize crops in five years there is little scope for advocating profitable fertilizer use until more drought resistant varieties become available. In areas with adequate and reliable rainfall the comments on fertilizer use on page 36 are also applicable to this zone.
An example of returns to fertilizer in a fairly dependable rainfall area is taken from the Geita district of Tanzania, in which it is assumed that 60 kg N plus 30 kg P applied to existing maize cultivars would give a farmer an incremental 700 kg of grain. Details are given in Table 4:1.

Table 4:1  Costs to Farmers of 60 kg N and 30 kg P Using Currently Available Fertilizer on Maize in Geita District  
(Prices in Current US$)

<table>
<thead>
<tr>
<th>Type of Fertilizer</th>
<th>Quantity Required kg</th>
<th>Cost of Fertilizer</th>
<th>Incremental Cost of Labour</th>
<th>Total Cost</th>
<th>Price Required for 700 kg of Maize to Give a 2:1 B:C</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAN</td>
<td>230</td>
<td>75.90</td>
<td>6.15</td>
<td>116.37</td>
<td>232.74</td>
</tr>
<tr>
<td>TSP</td>
<td>66</td>
<td>34.32</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


This table indicates that at the full cost of fertilizer the farmer would require a farmgate price of $232 per ton of maize to give a 2:1 B:C ratio. The actual price to the farmer in Geita at present is $78 per ton and the government provides a 66% subsidy on fertilizer to enable farmers to use it profitably.

As in West Africa many of the maize growing areas are a long distance from the main port of entry and in consequence fertilizer prices carry a considerable burden of transport and distributional costs. These can be reduced to some extent by the use of high analysis fertilizer (e.g. DAP and Urea), but despite quite good response ratios for maize there are few places in this zone in which the use of fertilizer on the available open pollinated varieties will provide a 2:1 B:C ratio at undistorted input and output prices.

Pesticides and Herbicides. The comments on pages 38 and 39 are equally applicable to this zone.

The Experience of Bank Funded Projects with Maize in the Savannah Zone of Eastern and Southern Africa

Only one of the five projects covered in the study of this zone included components for increasing maize yields through the use of new planting material and purchased inputs. This was the Mwanza project in Tanzania.
This project, dealing largely with maize intercropped with a variety of other crops, planned to raise yields through the use of improved seed and seed dressing. The planting of an improved variety was expected to raise maize yields by 110 kg per ha and seed dressing was reckoned to produce an average of 30 kg per ha increase. These expectations were in line with local experience but their impact was limited in the event by difficulties in multiplying and distributing adequate supplies of seed of a quality which commanded strong farmer demand. No fertilizer use was included under this project.

**Millet**

Bullrush millet is an important crop in the drier parts of this zone and is planted on about 2.5 million ha. Unlike in the main production areas of Nigeria it is seldom grown in mixtures with sorghum. Available technologies for improving its productivity will be considered under the headings of planting material, field practices and the use of purchased inputs.

**Planting Material**

The most productive breeding work on millet in eastern Africa was started at Serere in Uganda in the early 1950's. Out of that program has come several Serere Composites which have performed well in a number of locations. In the main millet growing area of the Sudan a selection of Serere Composite 2 has been released under the name Ugandi. This is a quicker maturing variety than the local cultivars which have been selected over many generations for a pattern of rainfall and soil which changed during the 70's and early 80's. If the current pattern of reduced rainfall and declining water holding capacity of the soils should continue then Ugandi might provide farmers with a means of maintaining their yields, if they could obtain a reliable supply of seed.

The provision of seed poses a major challenge. Millet is fully outcrossed, and the Western Sudan has a high population of wild millets which will cross with the new introduction and quickly reduce its productive capacity. Attempts to grow seed millet outside the main producing areas, to obtain isolation from wild types, have run into serious problems with bird damage. Farmers would require new seed every third year so that to influence all the millet growing area would require sufficient seed for 500,000 ha per year. This is a formidable task but with the large mechanised farms it should not pose an insuperable problem to have 4,000 ha of contract seed farms if the isolation from wild millets could be achieved.

The distribution of 2 million kg of seed per year in remote and rugged regions also poses a major challenge. In summary there is a variety available which could offset the erosion of yields resulting from declining water availability, but the practical problems of producing and distributing seed are likely to limit its usefulness for most farmers for some time to come.

Botswana and Zimbabwe have both made good use of Serere material to produce new varieties and Zambia has released WCC75 (based on material
from Nigeria), but in every case the problem of maintaining a constant supply of high quality seed of an outcrossing plant has limited the uptake of the new material.

Field Practices

Given the infertile soils, moisture stress and harsh climatic conditions under which this crop is grown, it is not easy to propose changes in existing practices with regard to cultivation (which is seldom used), planting dates or plant populations, which would result in significant increases in production. The parasitic weed striga is a serious problem in some areas, and encouraging farmers not to plant successive crops of millet on the same land can reduce the impact of this pest where resting is a possibility. In the Sudan the strains of striga which infect sorghum and millet are not the same. In consequence sorghum farmers can switch to millet when striga becomes serious on sorghum. Millet farmers are seldom able to switch to sorghum because of climatic constraints.

Purchased Inputs

Phosphatic fertilizer and seed dressing are the only purchased inputs proposed for use on this crop. On sandy soils with severe phosphorus deficiencies the use of phosphatic fertilizer can increase yields by 50%. With low base yields of 200 to 400 kg per ha even such a striking impact can be difficult to justify economically when the fertilizer has to be delivered to remote areas far distant from the main port. Assessment of the attractiveness of the use of fertilizer can only be determined in the light of the degree of severity of the deficiency and the costs and feasibility of transporting and distributing the fertilizer.

As with other cereal crops the use of seed dressing offers a low cost technology which can provide a worthwhile yield increment from time to time when there is an outbreak of seed borne disease.

The Experience of Bank Funded Projects with Millet in the Savannah Zone of Eastern and Southern Africa

The one project which included a major component for millet improvement was the Sudan Western Savannah. This project aimed at raising millet yields through the provision of seed, seed dressing and phosphatic fertilizer. The expected impact of these initiatives is given in table 4:2.
Table 4:2 The Expected Impact of New Technologies on Millet Production

<table>
<thead>
<tr>
<th>Input</th>
<th>Incremental Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 kg superphosphate</td>
<td>156 kg millet</td>
</tr>
<tr>
<td>seed dressing of local seed</td>
<td>27 kg millet per ha</td>
</tr>
<tr>
<td>use of improved seed</td>
<td>39 kg millet per ha</td>
</tr>
</tbody>
</table>


The response of 20 kg of millet per kg of P would indicate a situation of severe deficiency and an unusually attractive technical innovation. Fertilizer is expected to be used on 5% of the millet in the project area by year five and improved seed on about 1% of the area. The project has developed substantial stocks of seed, but farmers have yet to be convinced that it is superior to their own cultivars, and sales have been slow. Stocks of phosphatic fertilizer are also available but extension has yet to convince farmers of its benefits and sales are not up to SAR expectations.
5. THE HIGHLANDS OF EASTERN AFRICA

Background

The highlands of the Eastern half of Africa are scattered down the continent from Ethiopia to Zimbabwe. They occupy a comparatively small area of land but carry a concentration of population out of proportion to their size. This gives rise to the dominant constraint over much of the area, which is a shortage of land. The main challenge to farmers, therefore, is to intensify production per unit area of land.

Strategies for Intensification of Land Use

Many farmers in the highlands have soils which do not suffer from serious problems of micro-nutrient deficiency or panning. At the same time the climate is mostly favourable for plant growth, and moisture is not usually a major constraint. In consequence the main challenge to farmers is to maintain and increase the availability of plant nutrients to their crops. This calls for strategies which minimise soil erosion, create efficient recycling systems and draw in fertility from outside the arable plot. Traditionally these included:

(a) the use of perennial food crops (bananas and enset the 'false banana') with all the vegetative parts of the plant being returned directly to the garden or being fed to livestock and the manure being carried to the garden. This system will support a dense population and is found in Ethiopia, Uganda, Tanzania, Rwanda and Burundi;

(b) a switch to crops which give a greater output of calories per unit of land as compared to traditional staples. Mostly a move from cereals to root crops;

(c) cutting and carrying mulch from areas which cannot be cultivated. This is the basis of the farming system in Bukoba, Tanzania;

(d) using multiple cropping so that as much land as possible is in use for as much of the year as plant growth can be sustained; and

(e) using grass strips, trash lines, bunds and ditches to reduce soil erosion.

Traditional strategies are coming under strain in many areas because of increased pressure on the land. There is no longer sufficient grazing land to supply adequate manure from outside the arable farm to maintain its productivity. Population pressure cuts down on the availability of mulching material. It also encourages people to cultivate grass strips and trash lines and discourages the allocation of land to hedges or bunds to reduce soil loss. At the same time the need for cash encourages people to sell crops off their farms so that traditionally closed systems (e.g. the
banana system) in which there was little nutrient loss are now "leaking" nutrients through crop sales. But even when erosion is not a serious problem, good recycling is only capable of maintaining yields. Significant increases in production to match the growing population will demand corresponding increases in nutrients brought in from outside the existing system. The most obvious source of these is inorganic fertilizer. This has been the engine of intensification in other favoured agricultural areas throughout the world. There are two main factors which limit its uptake in the zone under discussion:

(a) much of the product of small intensive highland farms is for home consumption and does not generate cash with which to purchase fertilizer. It is essential in such areas for farmers to have access to a cash crop with particularly high returns to land (e.g. top quality coffee, fruits, horticultural products) from which income can be derived to pay for fertilizer for food crops; and

(b) many of these areas are a long way from a port of entry (e.g. Rwanda, Burundi, S.W. Uganda, E. Zaire and Malawi) and have poor local road networks because of hilly terrain. In consequence fertilizer is much more costly in such areas than it is in the coastal plains of Africa or other densely populated areas which have a much better developed industry and infrastructure. At present the only possible technical responses to this situation are the use of fertilizers with the highest possible nutrient content (e.g. DAP and Urea) and the maximum possible efficiency of fertilizer use.

In the face of these constraints to fertilizer use there is growing interest in the use of leguminous plants to supply additional nutrients into the system. These fall into three main categories:

(a) annual plants which are used as green manures. Typically seeds of a legume are undersown in a crop and the resulting plants are dug into the soil to provide additional N. This is a well known technology which has been advocated in parts of this zone for many years, but with virtually no adoption by farmers. The reasons for this rejection deserve closer analysis, but the extra labour involved and the sacrifice of food crops to a green manure must play a prominent role, particularly in multiple cropping systems. A green manure crop of 5 tons of green matter per ha would produce about 20 kg of mineralised N for the benefit of the following crop. This represents a comparatively low return to labour and land;

(b) annual food crops which have the ability to fix nitrogen. Phaseolus beans are the most widely grown legume in this zone. The amount of nitrogen which they fix varies according to the level of soil fertility, the health of the plants and the species of Rhizobia which develop in the root nodules. A figure of 6 kg of mineralised N per ha, which would be
available for subsequent crops, would represent the output from a good crop of beans. Other leguminous crops provide varying, but small, quantities of N for following cereals. Sub-tropical leguminous crops do not at present provide the potential for a major alternative source of supplementary N for farmers. Further research is still worthwhile into ensuring the optimum population of Rhizobia for any given crop through improved and simplified inoculation techniques; and

(c) leguminous trees which can be grown in association with crops. The best known of these is Faidherbia albida (previously known as Acacia albida). Farmers are usually well aware of its value where it occurs naturally and there is evidence that dense stands of the tree are the result of deliberate human protection in order to increase crop production. The tree loses its leaves during the wet season and therefore provides a green manure at the time of planting, whilst not shading the growing crop. There is good survey evidence of the impact of the tree on levels of N and carbon in the soil as well as improvements in cation exchange capacity and microbial activity. This is summarised in the University of California's 1978 publication "State of the Art: Acacia albida". The tree has the advantage of occupying little crop space, as thirty trees will provide cover for 1 ha. There is plenty of scope for research into clonal selection for rapid growth and ability to fix nitrogen as well as into methods of establishment to encourage farmer interest in planting trees rather than relying solely on natural spread. Other leguminous trees such as Leucaena have a potential in this zone but suffer from the disadvantage of occupying a significant amount of scarce crop land and demanding increased labour for chopping up and incorporating prunings. Agro-forestry as a developed system for increasing nutrient availability in this zone is in its infancy, but it deserves increased resources for research and development in the face of the problems of supplying farmers with inorganic fertilizers at prices which they can afford.

Experience of Bank Funded and Supervised Projects with Intensification of Land Use in the Highlands of Eastern Africa

The five projects selected to represent this zone are:

Rwanda: Gitarama Agricultural Production Project
Burundi: Kirimiro RDP
Zambia: Eastern Province ADP
Malawi: Dowa West RDP (IFAD)
Zimbabwe: National Agricultural Extension and Research Project (IFAD)
Two of the projects, situated in hilly areas in Rwanda and Burundi, specifically addressed the need to conserve soil in a situation in which land is in short supply. In both cases the method which was advocated was the use of contour strips of grass or shrub hedges to slow water movement and limit soil loss. The use of such strips has been an integral part of the national agricultural programs of these areas for many years so that the projects were not proposing a new concept. The problem with the technology is to provide the farmer with a plant which will slow soil wash and at the same time produce a useful product (e.g. fodder) but not compete with food crops. This is an ongoing challenge and as yet no fully satisfactory solution has been identified.

All of the projects propose the intensification of land use through:

(a) the use of more labour for better land preparation and weeding;

(b) the use of alternative planting material; and

(c) the use of inorganic fertilizer.

These will be considered in greater detail under individual crop headings. There are, however, broad generic constraints on this strategy. In the most densely populated areas the application of increased labour to such activities as better weeding can be expected to have a limited impact in what is almost a market garden situation with farm sizes of less than 0.5 ha. The performance of improved varieties is often linked to availability of plant nutrients and where these are in short supply the genetic potential of the plants may not be fully manifested. Raising the level of soil fertility can make both increased labour and better planting material much more productive, but providing fertilizer to farmers who are at the end of lengthy supply lines, and who have small plots and low incomes, continues to present formidable challenges with which these projects have had to grapple. Their success has been linked to a considerable degree to the size of the overall economy and its ability to carry the burden of price distortions to make fertilizer available. The greatest success in this respect has been in Zimbabwe and Zambia and the least in Rwanda and Burundi. Unfortunately there is no early prospect of an improvement in the ratios between grain and fertilizer prices. In 1976 it required 1.07 tons of maize to buy 1 ton of DAP at the international market prices. By 1987 it required 2.29 tons and the longer term outlook is for a ratio of about 2 tons of maize per ton of DAP, almost twice the figure of the mid 1970's. The supply of plant nutrients constitutes a critical factor in intensification of land use, and the projects under review have faced problems in achieving an improvement of supply to smallholders at undistorted prices.
Crop Production

A wide range of crops is grown in this zone of which the main ones are bananas, teff, barley, wheat, potatoes, sweet potatoes, beans, maize and groundnuts. Of these only the last two are included in the terms of reference of this study, and so only those will be considered.

Maize

The highland area under review can be broadly classified into two major zones according to the role of maize in the farming system. In the highlands of Rwanda, Burundi, Uganda and Ethiopia maize is a minor crop and plays a fairly insignificant role in overall food production. In the first three this is a result of a combination of climatic and land shortage factors which favour the growing of bananas and root crops which provide more calories per unit of land per year than maize. In the case of Ethiopia it is more closely linked to the dominance of the consumption of a staple food (injira) based on traditional grains (teff, wheat and barley) for which maize is not so well suited. From Kenya southwards to Zimbabwe maize has taken precedence over other staple foods in recent years and produced a maize dominated farming system. Although maize is frequently grown in association with other crops it is usually the principal crop in the mixture and the following sections will focus on those situations in which maize is either in pure stand or is the dominant crop. They will consider available technology for improving productivity under the headings of planting material, field practices and purchased inputs.

Planting Material

The main focus of maize research in this zone has been on the development of hybrid maize to provide the foundation for maize improvement programs. Zimbabwe was the first country after the USA to release a hybrid for commercial use. This was SR52 which has proved a highly successful hybrid over a considerable area of Eastern and Southern Africa. Kenya released its first hybrid in 1964 and has also been successful in producing a well adapted series of releases over the years. Tanzania, Zambia and Malawi have followed with their own material. Ethiopia still relies on imported hybrids which are adapted to its conditions.

The uptake of hybrid maize has been highly variable. It is widely used in Kenya and Zimbabwe for home consumption and sale. It is extensively grown as a cash crop in Zambia, whilst local maize is still being widely used for home consumption. It is grown on less than 10% of the maize area in the rest of the zone under consideration. There are three main reasons for these disparities:

(a) the existing hybrids are fairly soft dent types which are much harder to dehull by pounding than the traditional flint types. Those people who are accustomed to eating dehulled grain have
tended to reject existing hybrids for home consumption and will only grow them for sale to millers who can dehull the maize mechanically;

(b) seed production and supply has not been well organised. Hybrid seed has to be renewed each year and its production is more sophisticated than that of open pollinated varieties. Some parts of the region have yet to develop a production and distribution system adequate to meet farmer demand; and

(c) a lack of resources at the household level. Hybrid seed typically costs 8 to 10 times the market price of grain maize (which is a proxy for the price of home grown seed). It will only justify that high cost in the presence of adequate nutrients. Families with worked-out soils and no resources from which to buy fertilizer will be unlikely to benefit greatly from buying hybrid seed.

It is important to assess which of these factors is responsible for a low level of adoption in a given situation. For example in Malawi there is a good seed company which produces enough hybrid maize seed to have a surplus for export. There is a credit scheme through which farmers obtain fertiliser, but hybrid maize is only planted on 5% of the maize area despite many years of intensive extension. The reason for this is that the bulk of maize is grown for home consumption and there is a universal practice in Malawi of eating dehulled maize. In the Arusha area of Tanzania on the other hand the reason for farmers not planting more of their land to hybrid maize is a shortage of appropriate seed at the time when it is needed. Thus in Malawi the focus of work is to produce a hybrid which can be dehulled by pounding, whilst in Tanzania the need is for improved seed production and distribution.

In addition to hybrid material most countries in the region have produced composite varieties. Home grown seed of these can be replanted for three or four seasons and the initial purchase price is much lower than that of hybrids. None of these have gained widespread popularity. The main reason for this is that farmers who are only able to provide low levels of management see little difference between the improved material and their traditional cultivars. Farmers who are able to give higher levels of management would usually prefer to have the extra boost to yields offered by hybrids. Despite this fact there is little doubt that over the years the small percentage of land allocated to improved open pollinated varieties has had a considerable impact on the genetic make-up of the whole maize population. With the introduction of new maize streak-resistant material there is an added stimulus to encouraging the use of composites so as to distribute this gene through the local maize population.

Field Practices

Date of planting, plant populations and timely weeding are the three agronomic practices which have the greatest influence on maize yields. The notes on these three contained on pages 34 to 36 are largely applicable
to this zone. The dry season is often less severe in the highlands than in the sub-humid lowlands so that farmers have a better opportunity of carrying out land preparation prior to the coming of the rains. A higher proportion of the maize area can then be planted on time. Where this is not the case the main focus for technical change, in this respect, should be on strategies to help the farmer provide a plantable seedbed through work on the previous crop. In areas where ridges are used this can be achieved through a thorough late season re-ridging exercise which provides a fairly clean field at the start of the new season. Maize can be planted into the furrows or the sides of the ridges at the start of the rains and cultivation can then be provided by a thorough first weeding combined with ridge splitting. Essentially a judgement needs to be made in specific situations as to the trade-off between thorough pre-planting soil preparation and delayed planting.

With regard to plant populations it is equally important in this zone to assist farmers to achieve the optimum population for their soil conditions, variety and crop mix and to avoid blanket recommendations. The population density appropriate to a fertile soil could lead to considerable reductions in yield if used on a poor soil, as many plants would use nutrients to develop a vegetative structure but produce no cob. Experimental work in Malawi has shown that with moderate fertility a plant population of 27,000 to the ha consistently outyields the recommended population of 37,000 whilst at high levels of soil fertility the opposite is the case.

Early weeding (within 21 days of planting) has a substantial impact on yields in many situations. Labour constraints may not be as severe in this zone as in more land-plentiful areas, but extension staff need to ascertain which are the constraints that limit farmers' capacity to weed early. Telling farmers to weed on time is not an extension message. Providing farmers with a strategy to overcome the constraint which prevents them from weeding on time is a proper extension activity.

The Use of Purchased Inputs

The comments on the use of inputs on maize in West Africa contained on pages 36 to 39 are generally applicable to this zone. With more favorable soils, longer daylight hours in the southern parts of this zone, a more stable climate and better hybrids, the response ratios for these may rise to 24 kg of grain per kg of N in the presence of adequate P, for communities in which hybrid maize growing is a well established tradition.

The method and timing of fertilizer application is of greater significance in situations in which land constraints become more important than labour constraints. Typically the recommendation for fertilizer use will specify that all the P and some N be applied near to the planting stations at the time of planting and that the remaining N be applied when the maize is knee high. There is widely diverging experience as to the benefits to be derived from accurate fertilizer placement, the splitting of the application of the nitrogenous fertilizer and the timing of the top dressing. This is a factor of particular soil and, to a lesser extent, climatic
conditions. Universal recommendations are therefore not really useful and local experimental data need to be used in developing appropriate advice for particular situations. In doing this there are several factors which have to be borne in mind. These include:

(a) many farmers will be using much less than the recommended application and need advice as to the best means of using that amount of fertilizer. In particular, are there better returns to a light application to the whole field or a concentrated application to only part of the field? If there is to be only one application and not two or three then which is the best time for that one?

(b) farmers may be buying only one bag of fertilizer and need advice as to what type to buy and how best to use it. Neither research workers nor extension staff are ready to provide such help in many cases, and yet the majority of farmers may only be able to afford a small quantity of fertilizer of one kind;

(c) labour intensive methods of application (e.g. making a hole on each side of the stand, putting in a measure of fertilizer and covering it) may lead to considerable delays in that application. A decision is then needed as to the trade-off between accurate placement and optimum timing; and

(d) if farmers are being offered urea as a replacement for other nitrogenous fertilizers they must be concurrently offered a practicable method of application which buries the fertilizer. If this is not done then the advantage of the high N content of urea can be entirely lost through volatilisation.

This is a sphere in which considerable pressure is required on research and extension staff who tend to advocate an optimum solution to people who are unable to make use of it, and then avoid the much more complex challenge of producing answers which respond to the actual 'sub-optimal' situation faced by resource poor farmers.

A Summary of the Potential for Increasing Maize Yields in the Highland Zone

This document has presented a range of technical changes in maize growing which can raise yields. Whilst some are closely interlinked others can be adopted in isolation. The following table, derived from research in the southern highlands of Tanzania, provides an indication of the kind of progression in yields which can be achieved by the adoption of various technical changes. Each innovation is a progression from all the previous ones.
Table 5.1  A Summary of Innovations in Maize Growing and their Impact on Yield (kg/ha)

<table>
<thead>
<tr>
<th>Component</th>
<th>Content</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>Traditional variety, low fertility</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>one weeding</td>
<td></td>
</tr>
<tr>
<td>Improved variety</td>
<td>Use of improved seed with small increase in plant population</td>
<td>700</td>
</tr>
<tr>
<td>Improved fertility</td>
<td>Apply 40 kg N/ha and 15 kg P/ha</td>
<td>1,100</td>
</tr>
<tr>
<td>Time of planting</td>
<td>Move time of planting nearer to optimum for the area</td>
<td>1,300</td>
</tr>
<tr>
<td>Weeding</td>
<td>Carry out a second weeding</td>
<td>1,400</td>
</tr>
<tr>
<td>Plant population</td>
<td>Increase plant population from 25,000 to 35,000/ha.</td>
<td>1,500</td>
</tr>
<tr>
<td>Further improvement to fertility</td>
<td>Increase fertilizer by an additional 50 N and 20 P</td>
<td>2,100</td>
</tr>
<tr>
<td>Change to hybrid seed with improved timing of operations</td>
<td>Use of suitable hybrid planted within two weeks of start of rains and weeded within one month of planting.</td>
<td>2,800</td>
</tr>
<tr>
<td>Improved pest control</td>
<td>Appropriate action to control stem borers and other pests which may occur</td>
<td>2,950</td>
</tr>
<tr>
<td>Additional improvement to fertility</td>
<td>Add a further 50 kg N/ha and 30 kg P/ha</td>
<td>4,000</td>
</tr>
</tbody>
</table>

(Source Adapted from Maize Production in Tanzania's Southern Highlands: Croon, Deutsch and Temu CIMMYT 1984).

In areas where good research data are available it should be possible to build up a comparable table and then analyse the requirements for incremental labour at specific times to achieve these results, and the attractiveness of the financial returns to purchased inputs. Strategies would need to be developed from this analysis so as to assist farmers to lay hold of additional resources to carry out those activities which give the greatest increment per unit of investment of labour or cash.
The Experience of Bank Funded Projects with Maize in the Highlands of Eastern Africa

The five projects selected for this study clearly demonstrate the variations in the importance of maize in different parts of this zone. All of them include maize as a crop which will receive attention under the project but in the Rwanda and Burundi projects it occupies a minor place in the farming system and consequently in the expected benefits of the project. In the other three it is a major crop and the focus of a large share of project initiatives. All the projects included one or more of strategies aimed at changing planting material, agronomic practices and encouraging incremental input use.

Planting Material

Only the Gitarama project did not propose the use of alternative varieties. The Kirimiro project advocated the use of improved open pollinated material, but the total area involved was small with estimated maize areas being only 0.1 ha per farm. The Malawian project was expected to stimulate the use of the hybrid MH12 which is similar to SR 52. The project was expected to have increased the area under hybrid maize by 2,000 ha over five years. In the event the area under hybrid maize declined by over 50% during that period. The reason for this was that farmers do not use hybrid maize for home consumption and a change in the relative price of maize, groundnuts and tobacco encouraged farmers to move out of hybrid maize as a cash crop. Only had there been a hybrid available which farmers would use for home consumption would the project have been able to increase the use of hybrid seed in the face of adverse market forces. In Zambia the project was expected to increase the use of SR 52 hybrid seed. Although farmers prefer local maize for home consumption, the pricing system in Zambia encouraged the sale of grain to the marketing board and the purchase of subsidised machine milled flour for food. This, combined with the greater land availability for allocation to cash crops in Zambia, has resulted in a growing use of hybrid seed by small scale farmers. In Zimbabwe it was assumed that farmers were already familiar with the use of SR 52 and the focus of this aspect of the project was to encourage the use of alternative new releases. These projects provide an interesting progression from a situation with apparently no stimulus for using any improved maize (Rwanda) through a stage when some 5% of maize is planted to hybrids (Malawi) to where farmers are being offered a menu of hybrids (Zimbabwe). In no case is there an indication of the yield increment which could be expected from a change in planting material.

Agronomic Practices and the Use of Inputs

All of the projects expected that there would be yield increases as a result of improved management and the use of fertilizer. The table 5:2 provides details of the increases that were expected for the four projects which gave estimates of the impact of various interventions.
Table 5:2  Expected Increases in Maize Yield Deriving from the Changes in Management on Four Projects in the Highland Zone (kg/ha)

<table>
<thead>
<tr>
<th>Base Yield</th>
<th>Local with Fertilizer</th>
<th>Improved Without Fertilizer</th>
<th>Improved With Fertilizer</th>
<th>Hybrid With Fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kirimiro</td>
<td>800</td>
<td>1,300</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gitarama</td>
<td>745</td>
<td>-</td>
<td>995</td>
<td>2,995</td>
</tr>
<tr>
<td>Eastern Prov.</td>
<td>1,080</td>
<td>-</td>
<td>995</td>
<td>2,250</td>
</tr>
<tr>
<td>Dowa West</td>
<td>1,000</td>
<td>1,400</td>
<td>-</td>
<td>3,000</td>
</tr>
</tbody>
</table>

(Source: World Bank Staff Appraisal Reports).

The main inconsistency in these figures is the response to fertilizer as between Kirimiro and Gitarama. Both propose the use of the same quantity of fertilizer but one expects a response of 500 kg from improved management plus fertilizer whilst the other expects 2,000 kg from fertilizer alone. This last figure represents a response ratio of over 30 kg maize per kg N from open pollinated maize which would appear to be high. The Eastern Province and Dowa West figures for hybrid maize are based on almost identical response ratios. The first proposes 43 kg N and the second 116 N with a response ratio for the impact of fertilizer of 23 kg grain per kg of N which is an achievable figure in the favorable areas concerned.

The Zimbabwean project anticipated that increases in yields would derive from:

(a) early ploughing;
(b) early planting;
(e) increased plant populations to a minimum of 34,000 irrespective of soil fertility;
(d) fertilizer use;
(e) early weeding; and
(f) pest control.

These initiatives were expected to bring about a 50% increase in yields in the highland areas with good rainfall. Technically these are quite valid assumptions, what is less clear is how the farmers will be helped to overcome the constraints which have prevented them from adopting these practices in the past. A detailed survey of smallholder farmers in Zimbabwe by Collinson revealed a far more complex situation than that which is envisaged by the
project under review. 11/  This survey highlights the need for detailed work on the trade-offs which farmers have to make when resources are constrained, rather than assuming that late ploughing, planting and weeding are entirely a result of farmer ignorance and can be overcome by informing farmers of the importance of timely operations.

Groundnuts

Groundnuts are not a major legume in this zone as a whole and are of minor importance in the highlands of Ethiopia, Kenya, Uganda, Rwanda and Burundi. They are the major legume in parts of Zambia, Malawi and Zimbabwe. Two distinct types of groundnut have been grown in the past. The first is small seeded material both for home consumption and local oil extraction. The second is the large seeded Chalimbana nut which was grown for home consumption and the export trade as a confectionary nut. The export demand for this nut has fallen steeply in the recent past because its somewhat irregular shape does not fit well with the blanching equipment now being used in Europe. Research is under way to develop alternatives with the high quality of Chalimbana but a shape which is acceptable to the buyers. Because of this recent change in the emphasis in groundnut growing in the southern part of the region this paper will concentrate on nuts grown for home consumption or oil extraction.

The main constraints to groundnut production in this area are:

(a) fungal leaf diseases;

(b) low levels of nutrient availability; and

(c) serious labour clashes at the time of groundnut weeding.

The principal fungal leaf diseases are leafspots (caused by Cercospora and Cercosporidium spp.) web blotch (from Phoma arachidicola) and rust (caused by Puccinia arachidis). These have a major impact on yields, resulting in a reduction of from 35-75% when not treated. Despite the fact that groundnuts are capable of fixing nitrogen from the air their yields are sensitive to overall soil fertility, and differences in nutrient availability account for a considerable part of the variation in yield between research plots and farmers’ fields. Groundnuts are commonly grown by farmers whose major crop is maize. The planting and weeding demands of these two crops coincide. Because of the importance of maize to household survival it is the weeding of groundnuts which tends to be delayed when there is a temporary labour shortage, and this has an adverse impact on yields.

In addition to these major constraints the crop is locally subject to the virus disease, rosette, the incidence of empty pods (pops), if calcium is deficient, and a number of insect pests which can devastate the crop in some seasons.

11/ "To Feed Ourselves" Gov. of Zambia and CIMMYT 1985 PP 229-236.
The analysis of the potential to increase yields of groundnuts through changes in planting material, agronomic practices and the use of purchased inputs will focus on the constraints outlined above.

Planting Material

There are three broad categories of groundnuts grown in this zone. These are:

(a) long season confectionary type nuts of which Chalimbana is the most widely used. It has excellent eating qualities, but is a low yielder and has little resistance to the main diseases;

(b) long season nuts for oil extraction. Makulu Red is the best known variety in this category. It is a high yielder, has some resistance to disease but is not liked by many families for home consumption, which is the main use of the groundnut crop; and

(c) short season groundnuts of which Natal Common and Valencia are the most widely grown. These are particularly susceptible to leaf diseases and have a lower yield potential but better eating quality than group (b) above.

It can be seen that all of these varieties have some drawbacks. The main focus of research is to develop material with good culinary quality and resistance to the main leaf diseases. There has been some progress on the research stations but it is likely to be several more years before there are releases of new varieties which offer the farmers any real advance over what they now grow, in terms of overcoming the major constraint on yields imposed by leaf diseases.

Field Practices

Many years of work have demonstrated that groundnut yields can be increased by raising plant populations, planting early in the rains and protecting the plants from serious weed competition. Where farmers plant on ridges the distance between the rows is determined by the requirements of the maize crop for which the whole farm is planned and laid out. In consequence the groundnuts are planted on old maize ridges which are 90 cm apart which makes it impossible to achieve the right population for optimum yields. Where farmers are planting on the flat they may still plant the crop at wide spacing in an attempt to maximise returns per seed (the most expensive input) rather than to land. Efforts to raise population levels need to be planned and reviewed in the light of these factors.

In much of the main groundnut growing areas there is a serious conflict in labour demand in the early part of the season as farmers should plant maize, groundnuts and (quite commonly) tobacco at the same time and then weed them at the same time. Table 5.3 (on page 97) gives an example of this situation for Malawi. In this particular case there is a serious labour deficit in November and the first half of December and inevitably both
planting and weeding slip to a later than optimum date. What farmers need to know in such situations is the trade-off between delaying different activities and the possibility of using alternative varieties to flatten out the labour demand.

The Use of Purchased Inputs

Three classes of inputs are advocated for the groundnut crop in different parts of this zone. These are:

(a) insecticides for the control of aphids and a plant hopper (Hilda patruelis). Aphid control is possible but is seldom financially attractive under smallholder conditions because of the erratic nature of the attack. Hoppers can have a devastating impact on the crop but because they attack the plant underground it is difficult to provide control except by drenching the soil, which is uneconomic;

(b) fungicides to control leaf diseases. There has been considerable research on this problem and technical recommendations are available. Unfortunately a small farmer who has to use soil of low fertility and may have to delay weeding cannot obtain a worthwhile return to a spray control program. Only plots with research station yield levels are likely to be able to obtain an attractive return to spraying; and

(c) fertilizer to provide nutrients. Despite the fact that many farmers suffer low yields because of poor soil the response of groundnuts to fertilizer in this zone is erratic and can seldom provide an attractive recommendation for farmers. There is, however, widespread evidence that groundnuts benefit greatly from generous fertilisation of the preceding crop, and the focus of attention in this regard should be in exploring ways of helping farmers to achieve that goal.
Summary on Groundnuts

There is a wide difference between yields of groundnuts on research stations and farmers' fields in this zone. An example from Malawi illustrates the sources of some of those differences and is given in Table 5:4.

Table 5:4 Variations in Groundnut Yields Between Research Station and Farmers' Fields (kg/ha)

(1) Yield on research station with heavy fertilization of the previous crop 2,000
(2) Move to farmers' field under continuous cultivation with no fertilizer 1,000
(3) Stop spraying against fungal diseases because it does not pay 600
(4) Delay weeding by one month because of labour clashes 450


For resource poor farmers unable to improve on their general level of soil fertility or deal with their labour bottlenecks there is not an easy way to increase groundnut yields. The production of a variety with acceptable eating characteristics and a high level of resistance to leaf diseases would be a major source of progress. Until that happens the focus of attention has to be on the farming system as a whole to devise strategies for enabling farmers to overcome the constraints which they face with regard to plant nutrients and seasonal labour constraints. The latter are detailed in Table 5:3.
Table 6:3 Labour Requirements for Recommended Practices for Mixed Farm of 1.8 ha for Period September to February Compared to Family Labour Availability (Hrs. Per Crop Plot Per Task)

<table>
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<tbody>
<tr>
<td></td>
<td>M</td>
<td>G</td>
<td>T (1)</td>
<td>M</td>
<td>G</td>
<td>T</td>
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<tr>
<td><strong>Tilling</strong></td>
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<td>75</td>
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<td>24</td>
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<td><strong>Planting/transplanting</strong></td>
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<td>20</td>
<td>30</td>
<td>20</td>
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<td></td>
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<tr>
<td><strong>1st Fertilizer</strong></td>
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<td>42</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weeding</strong></td>
<td>70</td>
<td>100</td>
<td>50</td>
<td>25</td>
<td>40</td>
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<td><strong>2nd Fertilizer</strong></td>
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<td>42</td>
<td>0</td>
<td></td>
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</tr>
<tr>
<td><strong>2nd Weeding/Banking</strong></td>
<td>100</td>
<td>50</td>
<td>30</td>
<td>70</td>
<td>35</td>
<td>21</td>
</tr>
<tr>
<td><strong>Total labor required (3)</strong></td>
<td><strong>150</strong></td>
<td>75</td>
<td>45</td>
<td>170</td>
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<td><strong>Total labour per farm</strong></td>
<td>270</td>
<td>290</td>
<td>273</td>
<td>66</td>
<td>228</td>
<td>126</td>
</tr>
<tr>
<td><strong>Family labour avail. (2)</strong></td>
<td>248</td>
<td>170</td>
<td>140</td>
<td>135</td>
<td>244</td>
<td>191</td>
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<td><strong>Balance</strong></td>
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<td>-120</td>
<td>-133</td>
<td>+69</td>
<td>+16</td>
<td>+65</td>
</tr>
</tbody>
</table>

(1) M = Maize 1.0 ha.  
G = Groundnuts 0.5 ha.  
T = Tobacco 0.3 ha.  
(2) Family 2 adults; 1 child 13 - 18 yrs; 2 children below 12 yrs. Figures for availability from survey data of Kydd and Dorward.  
(3) Derived from MOA guidelines for crop production and survey data of Kydd and Dorward.
The Experience of Bank Funded Projects with Groundnuts in the Highlands of Eastern Africa

Three of the selected projects included components to foster groundnut production. On two of these, in Zambia and Malawi the crop was a major feature of the projects' agricultural component. The proposed intervention in both was a change of seed. In Zambia Eastern Province the only groundnut which could be grown by farmers, under a local regulation to foster the export industry, was Chalimbana. With an increasing internal demand for cooking oil it was agreed that farmers could grow Makulu Red. The project fostered this change and the SAR predicted an increase in yield from 500 kg per ha to 960 kg per ha for farmers who adopted Makulu Red (albeit with some depression in price per kg). There are no reliable survey data as to the yields which were obtained but there was some adoption of Makulu Red.

In Malawi the project provided credit for the purchase of certified seed of improved varieties. The use of this seed was expected to result in an increase in yield from 450 to 550 kg per ha. Once again no survey data are available as to the impact of the purchased seed on yields. The project was expected to encourage the purchase of 300 tons of extra seed over a five year period and in the event incremental sales reached 1,375 tons with the encouragement of favourable groundnut prices. This provides a good example of having the right strategy for a particular situation and can be contrasted with the hybrid maize seed sales on the same project which actually fell during project implementation, in response to crop pricing policies.

The Kirimiro project expected farmers to use fertilizer on groundnuts and thereby raise production on their small farms from 12 kg to 15 kg per farm. In the event farmers used the small quantities of fertilizer available on higher value crops and not on groundnuts.

It is interesting that whilst the disparity between research station and farmers' yields of groundnuts gives the impression of providing an easy crop with which to increase production there have been no Bank funded projects in this zone which have been able to do more than facilitate the flow of seed to farmers even though, in the past, raising yields through a range of interventions has been a major project component. More detailed research as to how to overcome the constraints of disease, soil fertility and labour bottlenecks will have to precede a major breakthrough with this crop.
6. **A SUMMARY OF SOME PRIORITIES FOR RESEARCH AND EXTENSION**

**Background**

This paper has highlighted a number of areas in which techniques have been developed to overcome the major constraints which limit the productivity of smallholders in SSA but which cannot be adopted by farmers because of labour, financial or institutional constraints. There has been an increasing awareness of this situation in recent years which is reflected in the growth of farming systems research. Yet an assessment of many extension services and the messages which they pass on from research would reveal that, in far too many cases, farmers are being treated as a homogeneous group, and advice is being offered which is impracticable or financially unattractive to many or even all the members of a farming community. Despite the widespread evidence of the remarkable speed at which attractive innovations have spread amongst African smallholders, there is still a tendency for both research and extension staff to dub farmers as conservative when they reject new technologies rather than questioning the appropriateness of the advice being offered.

It is now widely acknowledged that, for extension staff to be effective, they must understand the particular needs and constraints of individuals and groups of farmers within the communities which they serve. It is equally true that, in practice, this precept is consistently ignored as staff advocate agronomic practices or the use of purchased inputs which are inappropriate to large segments of the community. The same applies to research which continues to offer messages reflecting optimum conditions to people who constantly have to make compromises which preclude the possibility of always doing the right thing at the right time.

This paper has reviewed technical options for a number of crops under the headings of planting material, agronomic practices and the use of purchased inputs. In addition it has outlined some of the broader constraints of soil fertility and water availability which limit production. The following sections draw out a few of the salient points from the document which provide the opportunity for extension and research to offer farmers more appropriate help than they have sometimes received in the past.

**Planting Material**

**Opportunities for the Extension Worker**

This paper has noted three activities in which a sensitive and responsive extension worker could provide enhanced services to farmers.

The first involves the appreciation of the fact that the advantages of a particular new release are not necessarily scale and resource neutral. Extension staff can be helped to distinguish between groups of farmers who could benefit from a change to a newly introduced improved variety and those for whom it might offer increased risks with no corresponding advantages.
This does not just apply to a move from open pollinated to hybrid maize. It is relevant to a cassava with a fixed maturity period which subsequently deteriorates in the soil, to a high yielding sorghum which is daylight insensitive, to a cowpea which defoliates after fruiting and so produces no hay, or a rice which cannot tolerate long delays in transplanting. Staff need help to distinguish between the performance of a variety when planted and weeded at the optimum time or when grown by a resource poor family which will have to delay both of those critical tasks. At the same time such farmers can be alerted to those varieties which may be lower yielding under optimum conditions but are more tolerant of late planting, weed competition, poor soils and insect attack in unprotected situations.

The second concerns the development of a greater awareness of the potential of indigenous material and the possibilities that exist for moving locally developed cultivars to other comparable areas. Thousands of local cultivars have been selected over long periods of time but many are confined to small geographical areas. Modern communication has led to a greater spread of such material but there is often still great scope for sensitive and alert extension staff to stimulate and accelerate further movement. As conditions change in a particular area as a result of population increase, soil fertility decline, new pest outbreaks or changes in rainfall pattern, there are often opportunities to introduce locally selected material from elsewhere which has features which are adapted to the new environment. Quick maturing cultivars which can be used as catch crops under increased population pressure, or used in dry years are the most obvious examples, but cassava cultivars with some tolerance to mealy bug or mite and bananas tolerant of Black Sigatoka disease provide opportunities for an alert extension service to make a significant impact. There has been a tendency to under-rate the value of traditional cultivars to the point where extension staff may ignore them. In so doing they may miss the opportunity to provide a well worthwhile service to their clients.

The third is to act as a goad to the research stations to provide planting material which is responsive to the needs of the majority of farm households. This has been the subject of discussion for many years and yet there are still abundant examples of major plant breeding programs which do not take account of the real constraints faced by many farmers. This is equally applicable to national and to international programs. One good reason for this is that the extension staff themselves are often not really aware of the actual situation faced by the poorer members of the communities in which they work. The best designed system for promoting dialogue between research and extension will have little impact if the extension staff are not able to present the questions to which resource poor households are seeking an answer. Raising the sensitivity and awareness of extension staff is a prerequisite of the task of providing them with the means to bring pressure to bear on research workers to develop new varieties which meet the actual needs of the farming population. The importance of this is vividly highlighted by the fact that after forty years of breeding on sorghum and millet at internationally supported research stations in West Africa, less than five per cent of the crop is planted to such material because it does not meet most farmers’ needs.
Challenges to Research

A paper of this kind cannot presume to provide guidelines for national and international plant breeding programs but it has sought to highlight some of the constraints faced by farmers which could be overcome by the use of planting material tailored to those needs. Among the points which have been made, the following offer examples of current research and possible new initiatives which could have a widespread impact on the productivity of resource poor farmers:

(a) cassava, the modification of existing West African releases with mosaic resistance to provide material which will tolerate long periods of in-soil storage after it is mature and with an architecture which is better adapted to mixed crop situations;

(b) maize for the wet tropics with enhanced disease resistance. Maize for the savannah which is more tolerant of delayed planting, will effectively pollinate under drought stress, compares with the traditional flint varieties in its storage and pounding qualities and is tolerant of striga;

(c) sorghum for the drier areas of West Africa which has a higher proportion of grain to stalk than traditional cultivars but which is adapted to cultivation in mixtures with millet and is tolerant of striga;

(d) cowpeas which can be planted as an intercrop with sorghum and/or millet but which flower after the cereal is harvested. They should be semi-determinate (producing a single heavy flush of flowers followed by more sporadic flowering) to allow for one spray to control thrips. They should produce a large volume of hay and be resistant to striga. All these features exist in the genetic material available in West Africa and the challenge is to combine them;

(e) groundnuts for all areas with enhanced resistance to Cercospera infection. For the drier areas the development of rosette resistance. For the traditional exporters of high quality confectionary nuts there is a need for a replacement for Chalimbana types which retain the quality of that group but satisfy the processors' demand for a rounded nut adapted to their blanching equipment; and

(f) rice for the uplands which is tolerant of high levels of soil acidity, resistant to blast and sheath blight and responsive to nitrogenous fertilizer under typical current growing conditions. For areas dependent on seasonal flooding there is a need for material which is resistant to lodging and responsive to fertilizer whilst tolerating widely varying periods of growth in the nursery as farmers await erratic natural flooding. This needs to be combined with resistance
to rice yellow mottle virus which already exists in local cultivars.

It is encouraging that many of these subjects are the objects of current research programs, but past experience would indicate that there is a continuing need for an alert extension service to monitor whether their "packaging" takes full account of the constraints of so many smallholders. It is still easy to find references to recent varietal releases extolling their virtues when grown "with fertilizer, effective and timely weed control and optimum plant populations". No comment is then made as to their performance when one or more of these factors is beyond the capacity of a farmer.

Agronomic Practices

Opportunities for the Extension Worker

The two major agronomic constraints on crop production faced by large numbers of farmers are timely planting and timely weeding. Their relative importance varies between areas and crops and they are often interrelated. Timely planting is closely linked to land preparation and there is considerable scope for a more fundamental approach to this issue than is often adopted by extension staff. Many staff have been taught that cultivation is essential to plant growth and consequently do not question the need for or analyse the purpose of tillage in a given situation. There are no practices which are of universal application, but recent experience with low tillage techniques in Western agriculture has demonstrated that digging or ploughing are not necessarily the only effective way of obtaining good plant establishment. This knowledge has been slow to permeate many extension services, so that staff may be encouraging general land cultivation in situations in which it has few benefits and possibly some serious disadvantages in delaying planting. Consequently thorough land tillage is almost universally advocated whereas there are actually a number of options which are applicable to differing situations and which need to be assessed in the light of factors of soil, climate and farmer resource. These include:

(a) soils that are bare and self mulching at the start of the rains and require no general tillage;

(b) situations in which burning provides an adequate seed bed;

(c) situations in which seeds could be directly planted into previously cropped land and tillage be combined with first weeding;

(d) conditions under which tillage is a prerequisite of planting but could be carried out immediately after harvest when there may be a labour demand trough rather than at the start of the rains when there is a labour demand peak; and

(e) situations in which there is no practical alternative to tillage immediately prior to planting.
Once again this is a matter of raising the level of staff sensitivity to the logic of farmers' practices and the nature of their constraints and combining this with a sound training in agronomy.

The problems of timely weed control are more intransigent. Where ox cultivation is already well established there is often scope to extend its use to weeding and in some areas this could prove a transforming technical change. Elsewhere the need is often for assistance to individuals or groups to plan their cropping pattern in such a way as to stagger the demand for weeding. In other situations a modification of crop mixtures or plant densities could provide a greater degree of biological weed suppression. In many cases the need for weeding arises whilst farmers are still planting, and there is an urgent need to alert extension staff to the relative disadvantages of the delayed weeding of one crop as compared to the late planting of another.

The third main agronomic factor which influences yields is plant populations. All too often staff are given single recommendations for the spacing of a given crop. This is usually for a pure stand and has been developed under conditions of good soil fertility. The majority of farmers may be planting in mixed stands and using soils of widely varying fertility which are capable of carrying equally variable plant populations for optimum production. It is argued that extension staff need to be given simple clear-cut messages. Unfortunately farming situations are often not uniform and clear-cut and unless extension workers are trained to understand the principles underlying such matters as plant populations they will continue to provide advice which is erroneous or irrelevant to many of their clients. Research is often of little help to them in this respect.

Challenges to Research

A major gap in many research programs on agronomy continues to be the lack of investigation of sub-optimal solutions. Instruction manuals produced by research stations for extension staff still provide advice which is impractical for many farmers who cannot plant, weed or fertilize their fields in the very narrow period which is the optimum for each of their crops. There is still all too little advice on the trade-offs between carrying out different tasks at sub-optimal times. Because farmer constraints are often underestimated there is frequently little research into alternative varieties which may have lower absolute yield potential but which, through their tolerance of late planting or early weed competition, can offer opportunities for successional planting which could flatten out labour demand peaks. There is an increasing amount of work being carried out on mixed cropping, but extension staff are all too often given advice on spacing which is related to the research plot rather than farmer realities. The fundamental need is for increased exposure of research staff to farmers and their actual situations if there is to be a significant change in the pattern of agronomic research which has prevailed for the past fifty years.
The Use of Purchased Inputs

Opportunities for the Extension Worker

Apart from farm tools it is inorganic fertilizer which is the main purchased input used by farmers. Its use is typified by patterns of application which are out of line with current extension advice. Farmer practice differs from the recommendations in four ways. These are the quantity per unit area, the type used, the time and method of application. Typically farmers cannot afford the recommended dose and buy one bag of fertilizer. This often contains just one major element (N or P). Fertilizer is then only applied once rather than providing P in the seed bed and N as a top dressing. The recommended time of application is usually linked to split applications not single sub-optimal dressings and the method of application advocated may be labour intensive at a time of peak pressure on labour resources, so that farmer practice differs from extension advice. Given the high cost of fertilizer to the farmer and the nation there is an obvious need in many situations to face up to the reality of what farmers can and will do, and tailor supply and advice to meet their needs.

In terms of supply, extension staff can press for sales in smaller bags to give farmers greater flexibility (fertilizer sales in Malawi rose dramatically with the introduction of smaller bags) and call for compound or blended fertilizer which is adapted to a single application on the major crops. With regard to application they often need to press research to advise them on how low a level of fertilizer use will still be on the steep angle of the response curve. At present most extension workers tell farmers to apply their small amount of fertilizer to a portion of their field at the optimum rate recommended by research. Farmers on the other hand tend to spread the fertilizer thinly over as much of their farm as possible, but with no concrete advice or evidence as to just how thinly it can be spread before the response ratio falls seriously. Likewise extension staff need help in advising farmers on the best time to put on one application rather than two, and whether serious losses may result from using less labour intensive methods of application than those being advocated. The farmer often has to face the choice of a quick surface application at the correct time or a delayed but more labour intensive and careful placement when the main labour peak of weeding is over. Few extension staff are in a position to advise on the trade-off between these options because research seldom looks at sub-optimal solutions.

A further fertilizer related activity which offers extension staff the opportunity of improving on their service to farmers is the identification of possible problems with minor or micro nutrient deficiencies. If farmers are using conventional fertilizers correctly but getting little response this should alert extension workers to some other soil deficiency which needs correction. Large quantities of fertilizer are wasted in parts of SSA at present because of the absence of extension staff awareness of such factors which can be reported to research.
The other major inputs purchased by farmers are pesticides to control diseases and insects. The input-output price ratios for many of these have deteriorated in recent years and in consequence recommended application rates frequently offer farmers unattractive financial returns. Few extension staff are able to offer advice as to how best to use a smaller number of applications than that which is recommended. In consequence farmers adopt a "fire-fighting" approach which may be both ineffective and wasteful. As with sub-optimal fertilizer application, the extension staff are often poorly advised by research with regard to the sub-optimal use of pesticides, and yet it is these levels which are most commonly used by farmers.

Challenges to Research

As inputs become more expensive in relation to output prices the challenge to research is to intensify its efforts to identify ways in which farmers can obtain the best return from the small quantities of inputs which they can afford. Research staff will then be able to supply extension with the kind of information which they will need to carry out the functions outlined in the previous paragraphs.

Soil Fertility and Water Availability

Opportunities for the Extension Worker

This paper has highlighted the fact that, in some areas, there are generic problems with soil fertility and water availability which have a more profound impact on production than crop specific management factors. For some of these, such as the acidification of soils in the high rainfall tropical forest zone and the impact of highly erratic rainfall patterns in the Sahel, the extension worker must wait for new information from research which is still being developed. In other areas the problems are not so intransigent and some action is possible with widespread uptake in certain localities. Adoption is often linked to the degree of pressure which the farmer is experiencing and one of the critical lessons which extension staff need to be taught is to assess the correct timing of the introduction of a new technology. Help with the design of swamp drainage or the encouragement of the use of leguminous trees for fertility maintenance might be warmly welcomed in an area under severe population pressure and completely rejected where land is plentiful. The same principle applies to water harvesting, the use of live hedges for soil conservation and the mulching and use of compost on "backyard" trees and crops. Only by knowing farmers' real constraints will staff be able to judge when such initiatives are appropriate, and that judgement can make all the difference between rapid and widespread adoption (e.g. swamp drainage in recent years in Rwanda and S.W. Uganda) and almost complete rejection (e.g. swamp drainage in land plentiful areas of Liberia).
The Challenges to Research

There has been a steadily growing body of research work into some of the fundamental problems of soil fertility and drought tolerance in recent years which is most encouraging. At the same time there is a remarkable absence of any widespread scientific work on the nature of soil degradation on farmers’ field. Attempts to assess changes over time of soil pH, cation exchange capacity and soil density on farmers’ fields across much of Africa is almost impossible because so little work has been done. If the nature and rate of soil degradation are not known it is difficult to provide sound advice as to how it can be counteracted. In some cases it should be possible to identify fields from which soil samples were analysed 15 to 20 years ago and carry out a similar analysis. Only in this way will it be possible to counteract complacency on the one hand or unfounded scare statements on the other, and so develop a balanced strategy to deal with actual rather than hypothetical challenges to the maintenance of soil quality.

Agroforestry and water harvesting are receiving increased attention but are often still considered as peripheral to the main work of institutes by comparison with plant breeding. They merit much more serious consideration. The selection of clones of nitrogen fixing trees such as Feiderherbia albida is in its infancy and in some situations could deserve the same status and allocation of resources as the major crop breeding programs. At the same time the main weakness of a number of agro-forestry, water harvesting and on-farm soil conservation programs does not lie in technology development but in the assessment of its impact on labour demand at critical periods, on crop yields under farmer conditions, on risk (water harvesting can lead to crop drowning) and returns to land and labour. It is only when these are much more widely and thoroughly investigated that better adapted messages will become available to extension staff which in turn could lead to much wider farmer adoption.
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