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A Study about the Causes for Low Adoption Rates of Agriculture Research Results in West and Central Africa: Possible Solutions Leading to Greater Future Impacts

iSC SECRETARIAT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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Preface and Acknowledgements

This study about the causes for low adoption rates of agriculture research results in West and Central Africa: possible solutions leading to greater future impacts, has been carried out at the request of the interim Science Council of the CGIAR. It starts by making the point that the title of the study creates a wrong impression. As results presented in this report show, there has been a very significant degree of adoption of certain international and national agriculture research results in West and Central Africa. However, the impact has not been as high as could have been hoped for. Therefore, the expression “low adoption rates” should better be read as “limited impact”.

Sincere thanks are addressed to all the persons who have assisted me in collecting the necessary information for this study. Various staff members of IITA were extremely helpful in assembling relevant reports and data sets. In this respect I would like to express my special appreciation to A. Menkir for maize related materials, B.B. Singh for cowpea data and related matters and V. Manyong, for socio-economic research reports. Arrangements for the travel in Nigeria were made in the well known efficient manner by Mrs. J. Cramer, and staff of IITA’s travel office. My special thanks to all concerned.

The outstanding support received from different staff members of Sasakawa Global 2000 is acknowledged with particular pleasure and special gratitude. They allowed access to the large amount of valuable data available from work carried out by farmers with the assistance of SG 2000. In Nigeria, Dr. A.M. Falaki and his staff spared no efforts in providing me with a comprehensive overview of production results and related costs. The Directors in Ghana and Sierra Leone also provided very useful information.

It was a stimulating experience to carry out this study. I accepted this task in the expectation that it may contribute to the furtherance of agricultural research and development in sub-Saharan Africa. I do hope sincerely that these expectations will be met to some extent. I am convinced that significant progress can be made in agricultural development in sub-Saharan Africa. Excellent tools are already available for this, and even better ones are under development. But it needs the wisdom and will of a wide range of players to allow the farmers in Africa to significantly improve their living conditions. I do hope sincerely that substantial progress will be made in the near future.

Lukas Brader

July 2002

Executive Summary

This study, has been undertaken at the request of the interim Science Council of the CGIAR, and is meant to contribute to the adoption of a stronger regional orientation in the research planning of the CGIAR by looking at the following issues in relation to the West and Central African region:

- the appropriateness of currently available improved technologies given the agro-ecological and socio-economic conditions in the region,
- the efficiency of the present technology transfer mechanisms in widely reaching the producers,
- the bottlenecks (technical, institutional, organizational and cultural) that restrain the generation, dissemination and adoption of improved technologies, and
- implications of the above issues for the new CGIAR regionalization strategy, leading into recommendations towards an increased impact of its future research efforts.

To address these issues the adoption of improved maize and cowpea technologies has been used as an example. The review of relevant literature indicates that both maize and cowpea technologies have been adopted quite extensively by farmers in West and Central Africa. Maize research seems to have been most successful in this respect, and currently all the area planted to maize in the region is either occupied by improved varieties or by materials derived from them. The results obtained by farmers clearly show that the available improved maize and cowpea varieties can produce excellent yields, provided farmers have access in a timely manner to the necessary production inputs. Over the past 40 years maize has evolved from a subsistence crop to a food and cash crop. Originally maize was mainly grown in the humid forest zone, but the availability of well adapted germplasm has allowed it to become a major crop in the savannah zones, where growing conditions are more favourable for maize production. Consequently, the new maize technologies have affected in particular agriculture in these agroecological zones.

However, in the region as a whole maize and cowpea yields are still very low. The main reason for this seems to be the insufficient use of the necessary production inputs, in particular fertilizers. This affects very strongly agricultural productivity in this region where soil fertility is generally low and where pest pressure, especially for cowpea, is high. There are a variety of causes for the very limited input use including inconsistent government policies, inadequate infrastructure, insufficient private sector development, and high costs of inputs. The harsh reality in West and Central Africa is that farmers must not only cope with difficult crop production conditions, but also with mostly ineffective government policies and actions, and very poor support services. Notwithstanding this almost total lack of support, farmers have adopted to a very significant extent improved varieties, especially in the case of maize. A significant benefit is that currently all maize grown in the region is resistant to the major diseases, and as such the introduction of the new materials has significantly increased production security.

The efficiency of the present technology transfer mechanisms in widely reaching the producers was the second issue to be addressed. The performance of technology transfer mechanisms in the region has been quite variable in effectiveness over time. The rapid spread of improved maize varieties in Nigeria in the 1980s was due to the successful operations of the Agricultural Development Projects. Excellent examples are also available from other countries in the region. But, at present in West and Central Africa the agricultural extension systems are under-funded and often lack well motivated staff. In this region also NGOs try to fill the vacuum, but with the exception of Sasakawa Global 2000 and a small number of in particular church related groups, it is too early to judge the overall benefits of their actions.

The third issue referred to the bottlenecks (technical, institutional, organizational and cultural) that restrain the generation, dissemination and adoption of improved technologies. In order for a technology to be of interest to farmers it has to fit well into his/her production practices. As mentioned in the report international agricultural research in West and Central Africa originally followed the green revolution approach. In a sense that is surprising because of the lack of a number of essential conditions required for the success of that approach. These include a favourable production environment, in particular through irrigation, and effective access to technical information and production inputs.

Much more progress might have been made if from the start of international agricultural research in the region, critical production constraints had been analyzed, and if solutions to address them had been undertaken in a more pragmatic manner. Such an approach might have led to a situation where the availability of more sustainable production technologies would have been more advanced than is currently the case. However, the fact remains that the unfavourable socio-economic circumstances in the region would still have impacted in a negative manner on agricultural productivity.

The institutional problems are well known in the West and Central African region. National agricultural research and extension structures have in almost all countries been severely under-funded in particular over the last ten years. There is a significant number of well qualified staff but they lack adequate operational funds to carry out their work effectively. From an organizational point of view it will be important to further strengthen the ongoing effective collaboration between international and national agricultural research institutions. The national systems can, for example, draw significant benefits from collaborative projects through which they can complement their limited resources. At the same time, international research will be able to better focus on matters of direct interest to national systems.

Cultural differences in the region do not seem to have a marked effect on farmers' interest and capabilities to adopt new technologies. Provided that it can be clearly proven that a new technology fits into farmers' production practices and brings substantial benefits, without increasing production risks, it will usually be considered with interest by the farmers.

Opinions will most probably differ significantly on the implications for agricultural research of (i) agricultural developments over the last 40 years, and (ii) current socio-economic conditions in West and Central Africa (the forth issue to be addressed).

Without doubt there will continue to be a strong need for research aimed at increasing crop productivity and ensuring that natural resources and production inputs can be used most effectively. Research on sustainable production systems will remain a key element in this. This will require close collaboration between plant breeders and natural resource management specialists. Natural resources must be considered in the broad sense, i.e. it must also involve extensive pest management research. Labour productivity must be increased to reduce production costs and augment production efficiency. It might be worthwhile to analyze the type of research needed to try to overcome the shortcomings of insufficient government support. This could lead to the conclusion that more efforts should be undertaken to strengthen farmer organizations.

A critical problem is also the remuneration that farmers receive for their products and this will require further research on effective farm product storage, transformation, and commercialization. As noted earlier all these issues need to be addressed in a pragmatic manner by working closely with farmers in order to fully understand their needs. In the current situation in West and Central Africa this does not require a great deal of fundamental research. The agricultural development problems are of a very practical nature and need solutions accordingly. It has sometimes been argued that the more applied agricultural research should be undertaken by the national systems. Research must be undertaken in effective partnership with the national colleagues, and this means that both should be working on the full range of research problems.

Poverty as defined by the international development community is very widespread among the rural population of West and Central Africa. Reduction of poverty is a major goal of the CGIAR. The data presented in this report in relation to the activities promoted by Sasakawa Global 2000, show that farmers can earn a net income from improved maize production in the order of $200 to $600 per hectare per year. About similar incomes might be generated by effective cowpea production. These results are obtained by maize farmers that produce 4 to 6 tonnes of maize per hectare. These are good maize yields given the overall production circumstances in the region.

In West Africa the amount of arable land available per capita of the rural population is about 0.4 hectares, or some 4 hectares per family. It might therefore be speculated that the average farmer, when using effective maize production practices, could earn between $800 to $2400 per year. But if the average family size is eight persons and the poverty level is one dollar per person per day, than the average family must have a minimum annual income of $2920. Thus, given the current socio-economic conditions in West and Central Africa, there is little hope that significant numbers of farmers will be able to raise their income above the poverty line in the near future.

1. Introduction

The title of this study is misleading. As results presented in this report will show, there has been a very significant degree of adoption of certain international and national agriculture research results in West and Central Africa. However, the impact has not been as high as could have been hoped for. The expression “low adoption rates” should better be read as “limited impact”.

This study has been undertaken at the request of the interim Science Council (iSC) of the CGIAR. It is a follow up to the decision of the CGIAR to address more effectively the heterogeneity of the causes of poverty in different regions. As a consequence the system agreed to adopt a stronger regional orientation in its research planning and implementation, and to diversify and expand its partnerships to ensure that its limited resources are effectively leveraged in addressing the problems of the poor.

This study is meant to contribute to this new approach by looking into the following issues in relation to the West and Central African region:

- the appropriateness of currently available improved technologies given the agro-ecological and socio-economic conditions in the region,
- the efficiency of the present technology transfer mechanisms in widely reaching the producers,
- the bottlenecks (technical, institutional, organizational and cultural) that restrain the generation, dissemination and adoption of improved technologies, and
- implications of the above issues for the new CGIAR regionalization strategy, leading into recommendations towards an increased impact of its future research efforts.

The study has two components looking into the matter from different angles:

c) W.A. Stoop operating from the perspective of national research and development institutions in support of local client groups.
d) L. Brader, operating from the perspective of a consolidated CGIAR Center research program in support of a regional research agenda.

This part of the study concerns the second component. It analyzes the introduction and use of improved cowpea and maize technologies to look into the above mentioned issues. In view of the limited time available, only Nigeria has been visited to collect the necessary information and data, and experiences of this country have been used mainly for the development of the report.

2. Improved maize and cowpea technologies developed through agricultural research for West and Central Africa

Over the last 35 years improved maize and cowpea technologies for West and Central Africa have been developed mainly by IITA and its national partners, with significant inputs from CIMMYT for maize. Before the establishment of the International Agricultural Research Centers, breeding for the improvement of these two crops had been undertaken by a number of national programmes in the region. For both crops the major international agricultural research effort has been the development of pest resistant higher yielding varieties, to enhance both crop productivity and security. Originally these research activities were strongly inspired by the successes obtained in Asia through the introduction of high yielding rice and wheat varieties, combined with the increased use of agricultural inputs. Over the last two decades in West and Central Africa, more efforts have been devoted increasingly to the development of improved production systems, to better address the typical agroecological, socio-economic and institutional conditions of the region. This had led to different demands on the breeding programmes. To place these developments in an overall perspective it may be useful to briefly summarize the efforts undertaken by an International Agricultural Research Institute like IITA in planning an effective research agenda that addresses the wide-ranging needs of agricultural development in sub-Saharan Africa.

IITA was established in 1967 to provide in the tropics a high-quality international research organization devoted to finding ways as quickly as possible to increase the output and improve the quality of tropical food crops. To develop the first scientific programme for the institute a series of seminars was held. From these it was concluded that international agricultural research must strive, at least in the immediate future, to cover a wide range of activities to meet the broad array of research needs of agriculture in sub-Saharan Africa. Thus, in the mid 1970s the institute was working on 13 agricultural crops, as well as on three vegetable species and various forage legumes and grasses. Successive internal and external reviews made it clear that the institute needed to narrow its focus to use its resources most effectively. By 1989 the programme was reduced to six crops (maize, cassava, yam, cowpea, soybean and banana/plantain, and it has remained so since then. In the strategic plan for the period 1990-2000 it was noted that the green revolution approach remained valid for SSA, although it was recognized that the problems are more complex and the rate of achievement not as spectacular[4].

One of the reasons cited for the limited rate of achievement is the basic vulnerability of the predominant rainfed farming systems in Africa to rapid and irreversible degradation under more intensive cultivation with the improved technologies currently available. And the lesson from the experience gained was that improved germplasm and related technology components are a necessary condition but not a sufficient one for achieving adequate and sustainable rates of growth in food production. It is noted in the strategic plan, that there is no doubt that these powerful instruments (improved germplasm) for beneficial change need to be promoted more actively and effectively. But it is equally apparent that these interventions must be accompanied by the development of farming systems whose internal mechanisms make the use of external inputs more efficient and permit improved production technology to remain effective over the long term. Consequently, under IITA's 1990-2000 strategic plan, in addition to the crop improvement programmes, agroecological zone working groups were established. Plant health management research was also given increased attention. Thus, over the last decade, international research in the region has placed more emphasis on sustainability and less on yield increases. Both maize and cowpea offer good examples of this.

[4] IITA (1992), Sustainable Food Production in sub-Saharan Africa, IITA's Contributions.

2.1 Maize research

Since the early 1970s international research on maize has been directed at increasing the yield potential of tropical maize, while at the same time breeding for durable resistance to diseases and pests has also been pursued actively. This, because small-scale farmers are just as concerned about yield stability as about increasing yield (Buddenhagen, 1985[5]). A wide range of germplasm has been developed jointly with various partners since the 1970s and this has been widely used and distributed by national programmes in Africa, in particular in West and Central Africa. In regional trials the improved maize materials generally produced 50-100% more than the traditional varieties, under both high and low input conditions. Both open pollinated varieties and hybrids were developed.

Maize streak virus was the first disease for which resistant germplasm was developed and this was followed by resistance to downy mildew (*Peronospora sorghi*), rust (*Puccinia polysora*) and leave blight (*Bipolaris maydis*). During the 1980's and 1990's breeding for resistance to the parasitic weed, *Striga hermonthica*, was carried out with a high degree of success. In the meantime, breeding for increased yield and grain quality has been continued successfully. Early maturing maize varieties were developed for the humid forest zone and for the dry savanna, the latter since 1977 under the Semi-Arid Food Grains Research and Development Project (SAFGRAD). Over the last decade this work has been extended to breeding for nitrogen use efficiency and drought tolerance. This again has led to very promising results, offering new opportunities for the development of more sustainable production systems.

Table 1. presents examples of the range of yields obtained with improved varieties in field trials in West and Central Africa. It is evident that also in this region good maize yields are possible. The yield of over 11 tonnes per hectare was achieved in farmers' fields.

Table 1. Average yields from international maize trials carried out in West and Central Africa during the 1999 cropping season.

Type of maize	Sites	Varieties	Average kg/ha best performing variety	Average kg/ha least performing variety
Late maturing white grain	14	14	4426 (1284-8339)	3520 (1130-7017)
Late maturing yellow grain	13	7	4574 (1915-7544)	4121 (1624-7694)
Intermediate maturing white and yellow	12	10	4105 (1113-7713)	3238 (972- 6684)
Hybrid white	13	15	6163 (1480- 11270)	4357 (995-8066)
Hybrid yellow	12	10	5640 (3217-8365)	4690 (2227-8737)

[5] Buddenhagen, I.W. 1985. Maize diseases in relation to maize improvement in the tropics. Pages 243-275. In: Breeding Strategies for Maize Production Improvement in the Tropics, edited by A. Brandolini and F. Salamini. No. 100, Relazione e Monografie Agrarie Subtropicale e Tropicale, Nuova Serie. FAO and Instituto Agronomico per l'Oltremare, Firenze.

The increased knowledge base resulting from some 30 years of research on crop and soil improvement has been used in recent years for the development of more sustainable maize/grain legume rotations, whereby well adapted varieties of in particular soybean are effectively used for the partial replenishment of soil nutrients and organic matter. These systems involve the rotation of dual-purpose soybean with maize varieties with increased nitrogen use efficiency in combination with optimum fertilizer application. The grain legumes used in rotation with maize contribute to the improvement of soil fertility, while at the same time providing the farmers with food, as well as income by marketing their farm products. A drawback of using cover crops like mucuna, pueraria or lablab in food production systems to replenish soil nutrients and organic matter, is that they occupy the land without providing agricultural products and income to the farmer.

Currently the most widely grown maize hybrid in Nigeria, Oba Super 2, is of the group of materials with higher N use efficiency. It produces significantly higher yields than the traditional varieties at low N (the gains are equivalent to some 30 kg N/ha), and reacts like the traditional varieties to higher N. New open pollinated maize varieties with similar characteristics are now also ready for use by farmers.

In the Northern Guinea Savanna (NGS), the dominant maize production zone in West and Central Africa, locally available sources of organic matter are inadequate to meet farmers' requirements. Leguminous annuals and trees often do not fit into the socio-economic conditions of the farmers. Thus, over the last 10 years, the breeding objectives for soybean have been changed to develop so-called dual purpose soybean for the maize cropping systems in the NGS. Varieties were developed that produce a higher biomass in addition to good grain yields, fixing higher amounts of N. These improved materials are being increasingly used by farmers in the current maize-based cropping systems.

The soybean lines that are now available can produce about 2.5 tonnes of grains and 2.5-3 tonnes of forage per hectare, and there is every indication that further progress can be made. Comparison of the nitrogen fixed by these improved materials with a traditionally grown variety shows the positive N balance in a maize rotation and a significant increase in maize yield. Soybean varieties have now also been identified that can access additional soil P.

Maize in the NGS suffers very serious losses from the parasitic weed *Striga hermonthica*. This has become the most severe biotic constraint to intensive maize production in this agroecological zone. Maize varieties with partial resistance have been developed. However, strain variation in *S. hermonthica* complicates efforts to develop maize cultivars with stable resistance over wide geographic areas and over time. Resistance needs to be combined with other control strategies to attain sustainable control of striga.

The focus of the integrated control strategy for this problem is crop rotation with selected legume cultivars, in particular soybean. Soybean can bring striga seeds in the soil to premature, so-called suicidal germination, and thus reduce the pressure on the following maize crop. Very significant variation among soybean cultivars has been found with respect to the suicidal striga germination capacity. Therefore in the breeding program lines have been developed that show both superior agronomic performance and high stimulant production. Rotation with these soybean cultivars resulted in significant reductions in emerged striga in the subsequent maize crop.

The benefits to be derived of maize-soybean rotations incorporating the above mentioned characteristics of increased N-fixation by improved soybean varieties, better exploration of soil P, and striga control through the use of appropriate soybean and maize varieties, as well as the introduction of N use efficient maize varieties have now been extensively demonstrated under farmers' conditions. Economic analysis of these systems shows already an increase of the gross income of farmers of 50-70% compared to those following the current practices of mainly continuous maize cultivation. This reflects at the same time an equivalent increase in land-use productivity and with further spread there are excellent prospects for additional economic and environmental benefits.

There is no doubt that international agricultural research in Africa has made excellent progress in the development of highly improved and well adapted maize varieties, with adequate resistance to the major diseases. The introduction of these new technologies has stimulated significant increases in maize production in West and Central Africa. Details of this will be discussed later in this report. Moreover, the results described above should, in the coming years, offer excellent opportunities for significant increases in the sustainability of the maize production systems, while at the same time further reducing input costs.

2.2 Cowpea research

Cowpea is a popular crop in the dry savanna region of West and Central Africa for the production, under difficult growing conditions of limited soil fertility and rainfall, of protein rich food, as well as mineral and protein rich fodder for livestock feeding. Cowpea is traditionally grown in intercropping systems. This usually meets the farmers' objective of sustained production at minimal risks to satisfy subsistence and commercial needs. But these needs have increased in recent decades due to the increasing population in the region. The resulting reduction in arable land per capita needs to be compensated for through improved yields. There are over 20 different types of cowpea cropping systems in northern Nigeria of which millet-cowpea, sorghum-cowpea, millet-sorghum-cowpea, and millet-sorghum-cowpea-groundnut are the most common. Cowpea grain yields in these systems vary from zero to a maximum of 200kg/ha. Major production constraints in the intercropping system are low soil fertility, low plant population, heavy losses caused by a wide range of pests and diseases, lack of fertilizer and pesticides, shading of cowpea and groundnut by the millet and sorghum, as well as late maturity and poor yield potential of the local varieties.[6]

Farmers grow two distinct types of cowpeas, the one is a photo-insensitive variety that matures long before the cereals, and provide a source of food when supplies have dwindled. The other is a late maturing photo-sensitive cowpea that is planted in alternative rows with the early more erect type and produces abundant vegetation as it

[6] van Ek, G., A. Henriet, S.F. Blade and B.B. Singh. 1997. Quantitative assessment of traditional cropping systems in the Sudan savannah of northern Nigeria II. Management of productivity of major cropping systems. Samaru J. Agric Res. 14: 47-60.

spreads across the ground after the cereals have been harvested. It matures after the cereals, producing small amounts of grains, but significant amounts of fodder.

From 1970 onwards international agricultural research served as a catalyst of continued research on cowpea, building on work undertaken by national programmes in Nigeria, Senegal, Uganda and Tanzania. Emphasis has been until the 1990s on the development of high yielding grain producing varieties with increased resistance to the various pests. Materials have been developed with a yield potential of 1500-2000 kg/ha and with varying degrees of resistance to the following pests:

- cowpea aphid-borne mosaic virus
- cowpea yellow mosaic
- anthracnose (*Colletotrichum lindemuthianum*)
- bacterial blight (*Xanthomonas vignicola*)
- scab (*Elsinoe phaseoli*)
- brown blotch (*Colletotrichum capsici* and *C. truncatum*)
- Septoria leaf blight (*Septoria vignae* and *S. vignicola*)
- leafhoppers (*Empoasca spp.*)
- aphids (*Aphis craccivora*)
- bruchids (*Callosobruchus maculates*)
- Striga (*Striga gesneroides*).

The first improved materials produced during the 1970s did not meet the farmers preferences for seed quality and this had to be addressed in succeeding years before introduction could become successful. However, the highly productive and improved materials that subsequently became available during the 1980s continued to suffer from attacks by thrips (*Megalurothrips sjostedti*), the pod sucking bug (*Clavigralla tomentosicollis*), and in particular the pod borer (*Maruca testulalis*). Thus, the high yield potential of the new varieties could only be realized in case the farmers were able to apply insecticides. But reliable access to effective pesticides proved to be a problem on many occasions in West and Central Africa, and this has limited the introduction of these new materials. In addition the improved varieties were all grain types and therefore did not meet sufficiently the needs of farmers for fodder production. Interestingly, some of these materials are very extensively grown in a number of countries outside Africa.

Since the early 1990s international cowpea research changed significantly its focus. Through cross breeding with local varieties it concentrated on the development of so called dual purpose cowpeas, producing higher amounts of both grain and fodder. Close collaboration was established with the ILRI team in West Africa to effectively address fodder quantity and quality in the breeding and selection programme. These efforts resulted in the development of well adapted dual purpose cowpea varieties for the dry savannas. Excellent progress has been made and good material is now available and widely used. In addition varieties have been developed that can be grown during the dry season, either under limited irrigation or on the so-called flood recession plains. During the dry season insect pressure is much less and very remunerative yields can therefore be obtained. Efforts are ongoing for the development of integrated pest management approaches to address the remaining pest problems. The pod borer continues to be a major production constraint, and expectations are high for the use of biotechnological tools to effectively address this problem.

Table 2. gives an example of the results of trials in farmer's fields during the 2000 crop season in Kano State, Nigeria. In general they show a clear superiority of the improved materials over the local variety.

Table 2. Kano State cowpea trials in farmers' fields during the 2000 crop season. Grain yield in kg/ha, 2 sprays, 100kg/ha NPK 15/15/15

Variety	Zone I	Zone II	Zone III
IT95K-321-1	1333	1205	1017
IT95K-193-2	1459	1143	1316
IT90K-277-2	1250	1171	1521
IT95K-222-14	1250	888	887
IT95K-181-9	1333	502	1183
Local	792	670	784

2.3 Production systems research

Increased sustainability of the production systems in the dry savanna still remains a major challenge, but the availability of dual purpose cowpea may offer good opportunities for this. Joint research efforts in recent years have lead to very encouraging developments as described in the following paragraphs. These results are presented in a rather detailed manner, because of the very significant shift in research approach they represent and the promising results achieved. Like in the maize/soybean example it shows the benefit that can be obtained through an effective multidisciplinary crop and resource management research programme.

In the dry savannah cropping is cereal-based with sorghum and millet dominating. Intercropping with grain legumes is common in over 90% of the fields, with cowpea, together with some groundnut being the most common legume components. Traditionally 1 cereal to 1 cowpea row arrangement is used; the cereals are planted at the onset of the rains and the cowpeas 3-4 weeks later, Even though cowpea occupies 50% of the land its grain and fodder yields are between 10-20% of a sole crop of cowpeas. This is the same for local and improved varieties. Experiments have shown that cowpea should be planted as soon as millet has been sown to reduce the negative effect of shading. Efforts were made to develop alternative systems which minimize shading. A strip cropping system involving 2 rows of densely planted cereal to 4 rows of densely planted cowpea appeared to be significantly more productive, particularly when limited amount of fertilizer was applied to the cereal and one or two sprays were given to the cowpea. Experiments showed that sole crop of cowpea performs best. However, farmers showed the greatest interest in the 2:4 system because it provides them sufficient millet or sorghum for home consumption, and a large amount of additional cowpea for food and cash.[7]

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[7] Singh, B.B. and H.A. Ajeigbe. Improving cowpea-cereals based cropping systems in the dry savannah. Paper presented at the World Cowpea Research Conference III, 4-7 September 2000, IITA, Ibadan, Nigeria.

Over 50% of the total ruminant livestock in West and Central Africa are found in the dry savannah and they contribute towards livelihoods through the provision of meat, traction and manure, as well as income generation. In this way crop livestock integration is already a common feature of the farming systems. In the context of such systems cowpea is an important crop for farmers in much of the zone. It plays an important role with respect to improved food security, income generation, and improved resource management by the small holder farmers in the region.

When seeking to address the opportunities posed by the intensification of crop livestock systems in the dry savannas, it was apparent that a key component should be improved dual purpose cowpea varieties. What was equally clear, however, was that cowpea, livestock or cereal crops never function in isolation in farm fields or households in the dry savannas. Likewise there is a complex of interactions between the biophysical, economic, social and policy environments that influence farmers' decisions in these environments. To address this challenge, scientists from IITA with experience in cowpea research, ILRI for livestock and ICRISAT for cereals began to plan joint research in 1997. IFDC with an interest in the soils component of the system and the Centre for Overseas Research and Development of the Durham University (CORD) with experience in participatory research and resource management, together with scientists from national research and development institutions joined later.

Two major principles were elucidated. Firstly, the idea of using "best bet options" and secondly, to use a holistic, on farm approach to evaluate these options. Combining the best bet of each aspect of the integrated crop livestock system; varieties, crop husbandry and geometry, crop residue/manure management and livestock feeding constituted the best bet options. These options were designed to address the major needs in the mixed farming system, increasing grain and residue production, improving livestock output and preserving the natural resource base. The option of using optimal amounts of minimum inputs (in this case fertilizer for sorghum and an insecticide for cowpea) for maximum effect was also included.

The best bet options were to be assessed in a holistic manner together with farmers, taking account not only of the grain yields, but also of fodder yields, the livestock production resulting from feeding the fodder, manure output, and the effects on subsequent crops when the manure is returned to the same plots. This entails, among others, measuring nutrient cycling and determining the economic and social benefits or disadvantages of the best bet options as a whole.

Recognizing the challenges that were posed by this holistic approach, the initial strategy was to start small and in 1998 the trial was established at just one location in northern Nigeria in Bichi Local Government; 11 farmers volunteered to participate. Good information on village characterization was already available from a survey carried out earlier by scientists from ICRISAT and the Institute of Agricultural Research in Nigeria.

The package that was ultimately agreed upon for testing consisted of the following three treatments. All treatment plots received 3 ton/ha of manure at the start of the growing season.

1. Best Bet + (BB+), involved improved dual purpose cowpea and improved sorghum varieties that had shown to be well adapted to the agro-climatic conditions in this particular region. The sorghum and cowpea were planted in rows 75 cm apart, in the above described 2:4 arrangement. Minimum inputs included fertilizer application of a basal dose of 100 kg/ha NPK (15-15-15) and a topdressing of 20 kg N/ha on the sorghum rows only, and two insecticide sprays for post-flowering insects of cowpea.
2. Best Bet (BB), same as BB+ but without any inputs of inorganic fertilizer and insecticides.
3. Local (L), farmers' traditional mixed cropping system of sorghum and cowpea.

In 1999 thirteen more farmers joined the program in Bichi, as well as 23 farmers in Unguwan Zangi, a village in the same region in Nigeria. Two villages in Niger were also added. In 2000 the program was extended to a third village in northern Nigeria, Minjibir, the work continued in the two villages in Niger, and four villages in Mali were added. In each country the villages were chosen because they represent different farmers' circumstances which will facilitate the scaling up of the research results. The studies started in 1998 and were supported by socio-economic studies through household interviews. The increase of the number of locations was stimulated by the strong farmer interest. All the component options used were in themselves identified as a result of on farm experiments, and they are further modified as a result of interactions with farmers.

The quantities of grain and fodder in the BB treatments were greater than those in the local treatment. The most dramatic difference was for the cowpea grain at Bichi in 1998 when the BB+ treatment yielded more than double the BB and about 16 times the L. Fodder yields for BB+ were 1.5 and 5 times more than BB or L respectively. In 1999 these differences were less marked, partly because the yield of the local sorghum was higher than the improved sorghum. In many instances, although not quantified, this could also be related to an increase in the number of farmers adopting in their traditional practices some aspects of the best bet options, varieties and/or cropping patterns.

The data on livestock feeding in 1998 indicated that animals on the BB+ treatment gained significantly more weight during the last 6 weeks of the 16 week feeding period than those on BB or L. Whilst manure quantities produced by the animals on the different treatments did not differ significantly, the N content for BB+, BB and L was 1.35, 1.09 and 0.80% respectively. P contents were estimated as 0.28, 0.27 and 0.25% for BB+, BB and L respectively. Results from livestock feeding in the 1999/2000 dry season, indicated that again BB+ was superior to BB and L

Analysis of the nutrient dynamics shows strong positive balances for N and P for the best bet treatments. At the end of the 1999 crop season, the BB+ had a net positive balance of 40.5 kg N/ha and 14.3 kg P/ha; BB had a net positive balance of 33.7 kg N/ha and 13.4 kg P/ha compared to a negative balance of 28.3 kg N/ha and 0.67 kg P/ha for the local treatment (L).

An economic evaluation has been carried out to compare the costs, returns and profits among the three treatments. The data collected in Bichi during 2000 showed a total revenue of about Naira 33,000/ha for BB+ (1US$=Naira 110), 22,700 for BB and

17,000 for L. BB+ yielded the highest profit per hectare, about four times that of BB and L. The benefit/cost ratio was as high as 1.77 for BB+ compared to 1.18 for BB and 1.26 for L. The economic superiority of BB+ over L is clearly demonstrated by a marginal return of 1.84. That is an additional 84% of economic gains for farmers who adopt the improved system. A comparative economic analysis over time between the 1999 and 2000 cropping seasons shows an increase in total revenue and profit, and a reduction in production costs for material inputs and labour. Reasons could be the above mentioned positive nutrient balances and the farmers' better mastering of the new system over time.

Farmers' major reactions to the best bet options centred initially on grain yield, and subsequently the fodder yield, and perceived quality. The quantities of cowpea grain and fodder in the BB treatments were at least twice as much as those in the local treatment. It should be noted that the productivity of crops and livestock is only one dimension of this research, the implications for the human well being and the environment, as well as the interactions between these also need to be considered in the final analyses. The benefits of the two best bet options are probably best demonstrated by the fact that the village chief of Bichi recently stated that an estimated 90% of the farmers have now adopted elements of the system on their own.

3. Production statistics

Maize and cowpea production data for West and Central Africa have been derived from the FAOSTAT Production Statistics. In all tables and figures three year averages have been used. Details are presented in Annex I. To determine the potential impact of new maize and cowpea technologies resulting from collaborative international agricultural research data for the period 1980-2000 have been compared to those from 1960-1980. Improved technologies for West and Central Africa resulting from international agricultural research were released mainly from 1980 onwards.

In Central Africa over the period 1960-1998 the arable land area increased from 19.1 to 21.7 million ha, an increase of only 13.7% (Figure 1.). Arable land includes land under temporary crops (double cropped areas are only counted once), temporary meadows, land under market and kitchen gardens, and land under temporary fallow (less than five years). The abundant land resulting from shifting cultivation is not included in this category[8]. The limited expansion of the arable land area is explained by a significant reduction in the area of land left to fallow. To analyse this change the total of arable land is compared with the area harvested to annual crops (these crops include total cereals, fibre crops, groundnuts, soybean, pulses, root and tubers and vegetables and melons). In the 1960s the annual crops occupied about 43% of the arable land, while in the later part of the 1990s this percentage had increased to 59. This shows that the area of land under fallow must have decreased by some 17%. The amount of arable land available for the agricultural population has decreased from 0.70 to 0.37 ha per capita over the last 40 years. If the average family seize is estimated at eight, then the average area of arable land available per rural household would be about three hectares.

[8] FAO Production Yearbook 1999. FAO, ROME, Italy

For Central Africa there are no data available for cowpea in the FAO database. From the early 1960s to the end of the 1970s maize production increased by slightly over 20%, and this was entirely due to an increase in the area cultivated (Figure 2.). There were no consistent yield increases over that period. The situation is slightly better for the next 20 years, during which the production increased by over 80% and the area harvested by about 40%. Yields increased in particular during the 1990s although they continued to be low. It might be concluded that there has been a moderate effect of improved production technologies. The average yields are well below the potential of the improved maize varieties.

In West Africa over the period 1960-1998 the arable land area increased from 42.8 to 56.5 million ha or by 32% (Figure 3.). The area harvested to annual crops more than doubled over the same period, indicating a very significant reduction in the percentage of land under fallow. This is a well known fact in most countries of this region. Strangely enough, according to the FAO data, during the 1990s the area harvested to annual crops in West Africa had become larger than the arable land area (this shows a weakness of the FAO data, but more reliable alternative sources are not available). The amount of arable land available for the agricultural population has decreased from 0.69 to 0.51 ha per capita from 1960-1998. Taking again an average family size of eight would mean that about four hectares of arable is available per rural household in West Africa.

In West Africa maize production during the period 1960 to 1980 stayed unchanged , there was a slight increase in yield at the end of the 1970s but this was accompanied by a reduction in area cultivated (Figure 4.). This reduction in area cultivated can be attributed to the change in maize production in Nigeria (Figure 5.) As a result of the oil boom there was a very strong reduction in agricultural production during the 1970s in this country. A very large proportion of the rural population moved to the cities and the oil producing areas because of better employment opportunities and conditions.

There has been a very strong increase in maize production in the region during the 1980s when total production increased almost fourfold, the area cultivated tripled and yields increased by some 30%. However, these increases were not sustained during the 1990s. As discussed later in this report changes in government policies in a number of countries had a strong negative effect on agricultural development. The extensive introduction of improved varieties, which apparently had gained increased farmers confidence, has certainly contributed to these positive developments, as well as the increased use of agricultural inputs, in particular fertilizers. However, average yields are also in this region still on the low side. For the period 1999-2001 average maize yields in the world were 4,350 kg/ha, and 2,956 kg/ha for the developing countries as a whole.

The combined production trends for maize for West and Central Africa as presented in table 3, show again the very significant increase in production during the period 1978-87[9]. This coincided with the wide-scale introduction of improved varieties and the increased use of fertilizers. The annual increase of maize yield of 3.3% during the period 1978-87 demonstrated clearly that in this region improved technologies can

[9] Pingale, P.L. (ed.). 2001. CIMMYT 1999-2000 World Maize Facts and Trends. Meeting World Maize Needs: Technological Opportunities and Priorities for the Public Sector. Mexico, D.F.: CIIMMYT

have a very significant impact. The lower figures in the following ten years highlight that without supportive socio-economic conditions positive production developments cannot be sustained in this particular region. These aspects will be further considered in the following part of this report.

Table 3. Maize production trends in West and Central Africa.

Period	1966-77	1978-87	1988-99
Growth rate of maize area (%/yr)	-0.5	7.6	1.5
Growth rate of maize yield (%/yr)	0.5	3.3	0.4
Growth rate of maize production (%/yr)	0.1	10.9	1.9

Cowpea production in West Africa has increased from some 900,000 tonnes in the early 1980s to almost 2.7 million tonnes by 1998 (Figure 6.). During the period 1960-1980 there was no increase in cowpea production. The increases during the last 20 years are exclusively due to an increase in area cultivated. Average yields stayed around 300 kg/ha, about 15-30% higher than in the preceding 20 years. Nigeria produces about three quarters of the total cowpea production in West Africa (Figure 7.). In this country yields increased significantly during the 1980s but levelled off during the 1990s. This might be explained by the introduction of improved cowpea varieties during the 1980s. These varieties required the use of pesticide sprays to fully exploit their production potential. The socio-economic situation in Nigeria during the 1990s had a very negative effect on the costs and availability of agricultural inputs. The data for cowpea production in Nigeria show again the detrimental effect of the oil boom during the 1970s. The figures for Niger, the other major cowpea producer, show an almost seven fold increase of production over the last 40 years, and this increase is exclusively due to an increase of the area harvested (Figure 8.). There has been no consistent change in the low yields. The overall increase in cowpea production, notwithstanding the low yields, demonstrates the important role that this crop plays in the dry zones of Niger and Nigeria.

4. Adoption of improved maize and cowpea technologies: opportunities and constraints

Originally the Centres made improved germplasm available to national collaborators mainly through the international variety trials. Further use of these materials was supposed to happen at the initiative of the collaborating NARS. Since the mid 1970s this was expanded in West and Central Africa through the establishment of the Semi-Arid Food Grain Research and Development Project (SAFGRAD) which started in 1977. Its purpose was to enhance the generation and transfer of technology by fostering closer linkages between IITA, ICRISAT and the NARS. Strengthening of NARS capacity was also an important component of the project, to allow them to become active partners in the technology development and adoption activities.
The project covered four crops: sorghum, millet, maize and cowpea. Phase I of the project ended in 1986; under phase II four networks covering the four crops were established.

During the 1990s the technology transfer activities were completed with on farm research. This meant, in addition to working with the traditional national agricultural research institutes, direct collaboration with the extension services, and other relevant groups such as NGOs. In Nigeria, for example, this involved very close collaboration with the Agriculture Development Projects, for on farm testing, but also, to undertake farmer participatory research and, in certain cases, to promote farmer to farmer diffusion of seed of improved maize and cowpea varieties.

In particular improved maize germplasm has been widely distributed, and adopted by farmers, in West and Central Africa as various studies show. Analysing the impact of the above mentioned SAFGRAD project, Sanders et al. (1994)[10] note "It is a popular misconception that there has been little progress in developing new technologies for the food crops of concern to the SAFGRAD programme". Under the project maize and cowpeas research has been much more successful then research on sorghum and millet in introducing new cultivars and technologies.

Sanders et al. (1994) emphasize that in West and Central Africa maize performs an important supplementary role in the food supply situation. Because. in the drier Sudanic regions the early maize varieties become available before the sorghum and millet, thus providing food before the major harvest. These early maturing varieties were specifically developed for the particular agroecological conditions of the Northern Guinea and Sudan savannas. Fajemisin et al. (1997) note that the extra early maize varieties produce dry grain in about 90 days. They have good drought tolerance and resistance to striga, virus and fungal diseases. The development of these varieties has created niches for maize production, consumption and improved food security in a sub-region confronted by recurrent droughts and consistent decline in per capita food production.[11]

In Ghana approximately 55% of the maize area was in improved cultivars in 1992. Maize production increased from 265,000 tons in 1982 to 932,000 tons in 1991. In the early 1990s new maize cultivars occupied 65% of the maize area or 133,900 ha in Burkina Faso. From 1982-1991 in Ghana the internal rate of return to the public investment in the maize programme was 74%. The cowpea experience under the SAFGRAD project has been very similar to that of maize. Mali and Burkina Faso though small producers are good examples of this. It has been estimated that there would be a 50% decline in cowpea yields in the absence of the new cultivars. Critical issues for the successful spread of improved technologies are input supplies and reliable prices (Sanders et al., 1994).

Smith and Weber (1997) provide a good overview of the development of maize production in Nigeria following the introduction of improved varieties.[12] Their findings are summarized in the following paragraphs. They note that from an

[10] John H. Sanders, Taye Bezuneh and Alan C. Schroeder. 1994. Impact of the SAFGRAD Commodity Networks. USAID/AFR OAU/STRC-SAFGRAD 111 pages.

[11] Fajemisin, J.M., B. Badu-Apraku and A.O. Diallo. Contribution of the maize network to alleviating maize production constraints in West and Central Africa. Proceedings of a regional maize workshop 21-25 April 1997, IITA-Cotonou, Benin Republic: 126-137.

[12] Smith J. and G. Weber 1997. Fostering sustainable increases in maize production in Nigeria. In: Africa's emerging maize revolution, edited by D. Byerlee and Carl K. Eicher, London, United Kingdom: 107-124.

agroecological point of view only the Northern Guinea Savanna, which occupies 17% of western Africa, is appropriate for intensive maize production, because of the high solar irradiation and the low night temperatures. From a development perspective agricultural systems follow two different evolutionary paths: a subsistence-oriented path, driven primarily by population growth, or a market driven path, driven primarily by opportunities for cash cropping. Preconditions for the market-driven path are investments in transport infrastructure and technologies for crops with a natural comparative advantage. With fertilizer application, as occurs in market driven systems, the response of maize to applied nitrogen reaches about 30 kg of grain per kilogram of nitrogen in the sub-humid zones, whereas only half of that response is achieved in the humid zones.

In Nigeria maize production and consumption have grown rapidly over the past two decades. Growth in area and production can be attributed to the successful development of high-yielding varieties combined with the provision of cheap fertilizer, improved infrastructure, and extension services. In 1972-1973, the humid forest and the derived savannah together accounted for 60% of total maize production, the Southern Guinea Savanna for 24%, and the Northern Guinea Savanna and Sudan Savanna only for 16%. By 1983-1984, the Northern Guinea Savanna and the Sudan Savanna combined were the largest maize-producing area (54%), the humid forest and derived savannah produced just 23% of Nigeria's maize.

The IITA maize improvement strategy emphasized increasing yield potential, breeding for durable pest resistance, and development of distinct varieties for each ecosystem. Among the varieties emerging from this programme were TZB developed for the sub-humid zone, and TZPB, adapted to the humid zones. The release of TZB was a technological breakthrough for the Northern Guinea Savanna. The variety gave dramatically higher returns to land – six times as much as sorghum and millet, the traditional food crops, and seven times as much as cotton, the traditional cash crop. The pure white grain of TZB, its improved husk cover, and its resistance to ear rot all contributed to its acceptance, but farmers stressed that maize owed its new importance largely to its dual role as a food and a cash crop. When maize prices were unattractive maize could always be stored for home consumption. Aside from the development of suitable maize varieties, another precondition for the expansion of maize in the north was the development of transport systems.

The authors note that the performance of maize in Nigeria has been affected by the overall policy environment, which in turn has been dictated by oil revenues. During the oil bonanza from the mid-1970s to the early 1980s, inter-sectoral terms of trade moved strongly in favour of food crops in spite of an overvalued exchange rate and soaring food imports. Maize prices fluctuated strongly but remained well above the 1976 level throughout the period. Even with these incentives and fertilizer subsidy, food availability per capita declined. The increasing gap between urban and rural wages drew large numbers of rural people away from their farming communities to urban centres. Maize production alone fell by an average annual rate of 6.7% between 1973 and 1982.

In 1982, as oil revenues diminished, maize production responded strongly to the favourable terms of trade, policy incentives, and return migration to rural areas. Incentives for maize production were at their peak. By 1986, however, increased production and a currency devaluation led to the real price of maize to plummet in 1987, it was less than half the 1976 level. Maize prices recovered at the end of the 1980s after the government banned cereal imports. The fertilizer subsidy remained in effect, maize once again became highly profitable, and production grew at an annual rate of 5.3%.

In the Northern Guinea Savanna, group interviews confirmed that maize, considered a minor backyard crop in the mid-1970s, had emerged by 1989 as the lead crop in 90 to 100% of the villages surveyed in Kaduna and Katsina States. Virtually all farmers were using improved maize varieties in most of the survey villages. Local maize varieties had been completely replaced by improved varieties in most of the villages.

According to Smith and Weber (1997) it is by no means clear that the expansion of maize production is sustainable. Soil organic matter has deteriorated severely in market-driven systems of intensified cereal cropping, where high levels of fertilizer have led to high biomass removal, elimination of fallow periods, and reduced area in legumes. In the mid-1960s legumes occupied 22% of the cultivated area, whereas cereals were planted on just over half of the area.. By 1991, the area planted to legumes had declined to 11%, and cereal area had increased to 70% of the cropped area. Levels of organic mater appear to decline with intensive, continuous cereal cropping and are lowest in Katsina State, where intensive maize production was initiated 15 to 20 years ago, and highest in Bauchi State where maize is less important and short fallows still exist. In spite of the high level of fertilizer use in the Northern Guinea Savanna, the nutrient balance for potassium and micronutrients is negative, indicating soil mining and a high probability of nutrient deficiencies in the medium term.

Weeds remain by far the most important biological constraint, in particular in the population driven intensification systems in which land-use intensity is high and cash to pay labourers for weeding is scarce. These threats to sustainability are also linked to recent changes in government policy. Recently the Nigerian government removed the fertilizer subsidy and partially privatised fertilizer distribution. Preliminary interviews with farmers in the Southern Guinea Savanna after the subsidy was removed show that maize area is declining in 39% of the sample villages. Maize is being replaced by sorghum in the drier part of the Southern Guinea Savanna and by cassava and rice in the more humid areas.

Research issues related to the sustainability of maize production, and that are now addressed by research include, introduction of well adapted grain legumes (soybean offers good opportunities in this respect), development of Striga resistant maize varieties, and of varieties with improved nitrogen-use efficiency (see pages 4-5).

Smith and Weber (1997) emphasize that West Africa’s agricultural potential can be unlocked by using a very different approach from that which worked in the favourable and homogeneous areas of Asia. Production systems in West Africa, even intensive ones, require diversity to be sustainable. Technological priorities need to be developed within the context of a holistic vision of the agricultural systems in the mandate area. Clearly, success depends to a great extent on the ability to recognize and characterize the heterogeneity of the systems, to understand their dynamics, and to develop an awareness of how these dynamics interact with the evolution of threats to sustainability.

Elements needed for the sustainable development of maize production have been reviewed for some francophone countries by Adesina et al. (1997)[13]. They note that in the Northern Guinea Savanna of Nigeria Agricultural Development Projects (ADPs) and effective extension and input distribution systems, and market infrastructure were key determinants of success. However, in most of the maize growing areas of francophone West and Central Africa, the expansion of maize has been linked with the institutional support provided by the cotton development agencies. This included in particular provision of credit for the purchasing of animal traction equipment. They also provided farmers with improved maize seeds. Maize production also benefited from the CFA currency devaluation in 1994. It enhanced the profitability of local maize production and its competitiveness compared to imported maize.

Adesina et al. (1997) note also that the availability of early maturing varieties has allowed maize production in the semi-arid zones Burkina Faso, Mali, Niger, Senegal and Guinea to grow phenomenally. Annual growth rates of maize production in 1983-1992 have been high in Burkina Faso (17%) and Mali (7.5%). Production rates in the other countries, except Niger and Senegal, far exceeded the regional annual production growth rate of 4.1%. Most of the growth was due to area expansion except in Burkina Faso where yields have grown at the rate of 9.7% annually. Coastal countries have also experienced positive growth rates in yields, ranging from 8.1% in Ghana, to 4.1% in Cameroon, 2.9% in Togo, 1.8% in Nigeria and Côte d'Ivoire, and 1.3% in Benin. The demand for poultry feed is the major driving force for the expansion of maize production in the forest zones.

The authors mention that maize which was traditionally grown as a subsistence crop on small plots in home gardens, has been transformed into a commercial and profitable crop in the farming systems of different agro-ecological zones of West and Central Africa. But, market liberalization in for example Mali in 1986 and Cameroon created significant uncertainties for the farmers with respect to input supplies and destabilized existing marketing systems, which negatively affected maize production.

Maize development in Ghana also demonstrates the potential benefits that can be derived from improved maize technologies, as well as the need for effective support structures.[14] Tripp and Marfo (1997) note that despite Ghana's increasingly bleak economic prospects during the 1970s and its ailing agricultural sector, the research and extension system nevertheless proved remarkably successful in developing maize technologies that were attractive to farmers. The extent of this success became apparent when the Ghanaian economy began to revive in the mid-1980s and maize

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[13] Adesina, A.A., O.N. Coulibaly and V. Houndekon. Policy, devaluation, and profitability of maize production in West and Central Africa: Comparative analysis of Cameroon, Benin and Mali. Strategy for sustainable maize production in West and Central AFRICA. Proceedings of a regional maize workshop 21-25 April 1997, IITA-Cotonou, Benin Republic: 53-92.

[14] Tripp, R. and K. Marfo, 1997. Maize technology development in Ghana during economic decline and recovery. In: Africa's emerging maize revolution, edited by D. Byerlee and Carl K. Eicher, London, United Kingdom: 95-106.

production rebounded at a surprisingly rapid rate. Maize yield increased in large part because of the widespread adoption of improved technoloies.

The relative importance of maize in different areas of the country has changed over time. Maize was traditionally an important crop for home consumption in parts of the forest and coastal savannah zones. Presently, maize production in the transition zone and the Guinea Savanna accounts for more than half of the maize planted in Ghana. Farmers generally valued the new maize varieties for their superior yield, fertilizer responsiveness, early maturity, and resistance to lodging. Originally there was some concern about the storage quality because of inadequate husk cover, but maize breeding has addressed this.

The adoption of improved maize production practices during the 1980s has undoubtedly contributed to the growth in maize production and yields since the late 1980s. Adoption of an improved variety, fertilizer (90-40-40 N-P-K), and adequate plant population increased yields from 1.8 tonne/ha to 3.5 tonne/ha. Without question improved maize production contributed to the decline in the real wholesale price of maize throughout the 1980s. The authors note that input policy has a significant impact on maize production, as shown by the fact that the removal of the fertilizer subsidy in 1990 precipitated a sharp decline in fertilizer use. This in turn led to a sharp reduction in maize production.

Although more research is needed on developing new varieties suitable to Ghana's growing conditions and market demands, increased attention needs to be directed toward soil fertility and crop improvement. With fertilizer only marginally profitable in many cases without the fertilizer subsidy, efficient methods of combining chemical fertilizer with other management techniques need to be developed. Weed control is another management challenge. Weeds are the single most important limiting factor on many maize fields in Ghana.

One of the major problems having led to a reduction in maize production during the 1990s has been the disarray in the input market in a number of countries following the implementation of the so called structural adjustment programmes. The events in Nigeria are a good example of this and a recent study provides further details (IFDC, IITA, WARDA, 2001).[15] It found that the agricultural input markets are fragmented and underdeveloped. During the 1990s, Nigeria introduced input market reforms without adequate supporting developments in institutional capacity and human capital formation. As a result the use of fertilizer decreased from over 500,000 nutrient tonnes in 1993/94 to approximately 100,000 nutrient tonnes in 1999/2000. The use of improved seeds and pesticides also decreased. Because the input markets are not functioning properly, the transaction costs of acquiring inputs are high and even then inputs are not readily available on time and in good quality. Quality control regulations are not enforced properly. In the seed sector, funding arrangements for the National Seed Service remain inadequate and uncertain for performing training and quality control functions. Dealer networks in rural areas are not well developed, and farmers must travel long distances to acquire inputs.

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[15] IFDC, IITA and WARDA, 2001.Agrixultural input markets in Nigeria: an assessment and a strategy for development. 31 pp.

The study considers that the private sector in Nigeria has the potential to supply agricultural inputs in a cost-effective manner. However, because of the public sector monopoly in the past, these organizations and structures did not have an opportunity to develop the necessary skills needed for efficient marketing and market development.. Years of neglect and mistrust have left the private sector handicapped to perform efficiently. This study concludes that macroeconomic instability, policy inconsistency, lack of access to affordable finance and market information, and poor enforcement of quality mechanisms further discourage the active participation of the private sector in the input market development. Macroeconomic instability resulting from the depreciating exchange rate remains the single most important macropolicy factor that inhibit the growth in fertilizer use and the development of input markets.

Manyong et al. (2001) consider that agricultural research by national systems and international institutes has contributed to the increase of maize production and productivity in West and Central Africa over the last three decades.[16] Gains to consumers can be shown through the trend of the maize retailer's real price in the market. In Nigeria the real consumer price for maize did not show any significant increase over time compared to that of all other food commodities shown by the composite consumer price index.

It may be useful to end this review of a number of publications related to the opportunities for and constraints to the introduction of new maize technology with a summary of a paper by Byerlee et al. (1994) on the impact of maize research in sub-Saharan Africa.[17]

Byerlee et al. (1994) highlight that the record of technical change in maize production (in sub-Saharan Africa) is less gloomy than the widespread image of stagnating African food production would suggest. Many countries in sub-Saharan Africa have introduced improved maize technology with considerable success. Although maize yields in Africa have lagged yields in other regions, the overall gains in productivity to the scarce factor, which in much of Africa is labour, may be quite comparable to gains in other developing regions. However, the adoption of improved technology has been patchy. Often quite different results are seen in neighbouring countries, sometimes reflecting the varying availability of appropriate technology and sometimes reflecting constraints induced by institutional performance and policy. Improved varieties and hybrids are available for most areas, but appropriate crop and resource management technologies, especially for maintaining soil fertility and labour productivity, often are lacking.

The rate of adoption of improved maize varieties in 1990 as presented by Byerlee et al. (1994) is given in table 4. Two estimates are used, representing the lower and upper bounds of adoption of open pollinated varieties (OPVs). The lower bound is defined as the area sown to seed purchased in the year of the survey. The upper bound

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[16] Manyong, V.M., K.O. Makinde and O. VCoulibaly. 2001. Economic gains from maize varietal research in West and central Africa. Paper presented at the Fourth West and Central Africa Regional Maize Workshop, 14-18 May 2001, IITA, Cotonou, Benin Republic.

[17] Byerlee, D., P. Anandajayasekeram, A. Diallo, Batayu Gelaw, P.W. Heisey, M. Lopez-Pereira, W. Mwangi, M. Smale, R. Tripp, and S. Waddington, 1994. Maize research in sub-Saharan Africa: an overview of past impacts and future prospects. CIMMYT Economics Working Paper 94-03. Mexico, D.F.:CIMMYT.

reflects the total area sown to improved germplasm, including seed of improved OPVs that was saved by farmers or passed from farmer to farmer. The authors note that 33-50 % of the maize area in sub-Saharan Africa was planted to improved materials or modern varieties (MVs) in 1990. And they stress that if the large developing countries with large commercial or irrigated maize sectors are excluded (China, Argentina and Brazil), progress in adoption of improved maize varieties has almost been as rapid in Africa as in Asia and Latin America. The review showed that improved seed has had a fairly extensive impact in much of the maize growing area of Africa, whereas fertilizer technology has been rather less successful.

Table 4. Area sown to improved maize varieties in Central and West African countries.

Country	**Total maize area 000 ha**	**% area sown to improved OPVs**		**% area sown to hybrids**	**% area sown to improved germplasm (MVs)**		**% of MV area with CG germ-plasm**
		Min.	Max.		Min.	Max.	
Nigeria	1,500	22	87	2	24	89	60
Cote d'Ivoire	691	14	42	4	18	46	88
Ghana	465	16	48	0	16	48	91
Benin	454	9	27	1	10	28	61
Togo	296	7	18	3	10	21	81
Burkina Faso	216	15	70	2	17	72	48
Cameroon	200	20	67	1	21	68	72
Mali	170	36	50	0	36	50	27
Senegal	117	100	100	0	100	100	100

Byerlee et al (1994) conclude that the experience with maize technology in Africa provides ample evidence that small-scale farmers, provided with well-adapted technologies and appropriate institutional support, will adopt improved seed , including hybrids, and complementary inputs as quickly and extensively as farmers in other regions. However, adoption sometimes has been patchy and the impact less than expected, in part because of deficiencies in local research and institutional support and because of inappropriate macroeconomic policies. Thus the development of improved technologies in Africa needs to place a special premium on ensuring efficient input use and maximizing returns to scarce labour and cash in the early stages of adoption. This implies a strong programme of on-farm research and extension with effective farmer participation to develop flexible and site specific recommendations.

The above examples demonstrate that various studies have been undertaken to analyse the opportunities and constraints for the introduction of improved maize technologies in West and Central Africa. They all come to similar conclusions:

(i) improved varieties can lead to significant improvements in maize production in the region,
(ii) effective government policies, in particular those related to input supplies, are essential for the development of maize production, and
(iii) more intensive maize production in West and Central Africa encounters significant sustainability problems that require innovative approaches to soil conservation and effective input use.

Regretfully for cowpea the number of such studies is much more limited. The most comprehensive study concerns Ghana and has been published by Dankyi et al., 2000.[18] They note that in the early 1980s in Ghana the top three production constraints identified were: (i) lack of improved varieties/low yield potential of local varieties, (ii) insect pest damage, and (iii) low plant populations.

These matters have been addresses under the Ghana Grains Development Project from 1980-1997. The research and extension efforts undertaken have had a very significant impact on farmers' productivity and incomes. Cowpea production in 1980 was estimated at 17,000 tonnes from about 100,000 ha; in 1997 it had increased to an estimated 80,000 – 100,000 tonnes from 140,000 to 160,000 ha. This means that the increase of production was in the first place due to increased yields from an average of some 170kg/ha to about 600kg/ha; a 250% increase over a 17 year period.

Dankyi et al. (2000) have carried out a study to (i) assess the extent of use of improved varieties and crop management technologies (insect control with insecticides and row planting to enhance plant population), (ii) find out farmers' perception of the effects of the technologies on their productivity and incomes, and (iii) examine gender roles in cowpea cultivation. It must be noted that the improved cowpea varieties were determinate and farmers were encouraged to plant them as sole crop. These were essentially new practices especially to the farmers in the Guinea Savanna zones. Five of the six improved varieties recommended originated from IITA, two were of medium maturity, one was early (originating from Ghana), and three were extra early. The yield potential of the IITA varieties ranged from 1,750 – 2,200 kg/ha, the one from Ghana had a yield potential of 1,500 kg/ha.

The survey was carried out in eight districts, in each district five villages were randomly chosen, and in each village eight farmers were again randomly selected. Thus the total sample size was 320 farmers. The adoption rates for the improved technologies were: improved varieties 69.7%, row-planting 70.7%, pre-flowering insecticides 82.8% and post-flowering insecticides 25.8%. Over half of the farmers obtained their seeds from official sources, while about 21% of them selected seeds from their own fields or obtained seed from other farmers. Nearly 28% of the farmers purchased their seed from the grain market. The recommended row planting increased

[18] Dankyi, A.A., B, Asafo Adjei, M.A. Hossain, K. Dashiell, H.K.Adu-Dapaah and V. Anchirinah. 2000. The adoption of improved cowpea technologies in Ghana. Paper presented at the World Cowpea Research Conference III, 4-7 September 2000, IITA, Ibadan, Nigeria.

dramatically the plant population by 400-600% over traditional farmers' practice (from 20,000 – 40,000 to 125,000 – 167,000 plants/ha). Farmers had difficulty in identifying the appropriate post-flowering insecticide. For most farmers the grain output, income, profit, and the quantity of product sold or stored, increased.

Over 85% of the farmers said their cowpea production has been increasing following the adoption of the improved technologies. Of those farmers whose cowpea production had increased, 80% said cowpea had become more profitable than other food crops like maize and cassava, while 13% attributed the increase to the fact that it is a staple food that is widely consumed. About 7% of the farmers gave other reasons for the increase in production. For those farmers who responded that their cowpea production was decreasing (12.5%), the main reason given was high cost of inputs (insecticides). Their yields were low, because they could not afford to purchase insecticides.

Male adults carry out most of the strenuous field activities like land preparation, weeding and spraying. Females are mainly responsible for winnowing after threshing and sale of produce. The whole family is involved in planting and harvesting, while storage is done by either men or women.

In Nigeria an adoption study on the introduction of improved crop-livestock management systems has been carried out recently (Kristjanson et al., 2000).[19] The study uses georeferenced community-level data to determine the adoption of improved cowpea in northern Nigeria. One of the objectives was to find out which factors at the community or village level are significant determinants of adoption of improved dual-purpose cowpea varieties and management techniques. In the entire study area 60% of the farmers cropped their land continuously. The most important reason for the adoption of a particular cowpea variety was, first high grain yield, second adaptability to the local environment and third fodder yield.

An increase in the area planted to cowpeas was reported by 48% of the communities. Population pressure seems to influence uptake of improved dual-purpose varieties. 8% of cropland was sown to improved dual purpose cowpea within the low population density domain, whereas 15% of the total area cropped was planted to improved dual purpose varieties in the high population density domain. With good wholesale market access respondents reported increases in both area under cowpea and the uptake of improved cowpea varieties. Of all the farming households 75% use cowpea fodder to feed their livestock and to receive income from sale of fodder. Intensity of adoption was significantly and positively influenced by both the perceived importance of livestock and the number of livestock owned. Cowpea was considered very important and important in almost all locations.

Results of the study showed also that the more often the extension agents visit the farmers, the less likelihood that new cowpea varieties are being adopted. It seems that the generalist extension agent does not sufficiently understand all the diverse material

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[19] Kristjanson, P. I. Okike, S. Tarawali, R. Kruska, V.M. Manyong and B.B. Singh. 2000. Evaluating adoption of new crop-livestock management technologies using georeferenced village-level data: The case of cowpea in the dry savannas of West Africa. Paper presented at workshop on "Understanding adoption processes of natural resource management practices for sustainable agricultural production in sub-Saharan Africa." ICRAF, Nairobi, July 3-6, 2000.

they are expected to extend to farmers. Consequently, the authors suggest that since traditional dissemination pathways do not appear to be working, national and international agricultural researchers need to either strengthen these institutions or explore other pathways for dissemination of their results. Another possible interpretation is that new technologies must be attractive enough to stimulate horizontal farmer-to-farmer diffusion.

Kristjanson et al. (2000) conclude that the adoption of improved dual purpose cowpea varieties appears to be a win-win situation with respect to improvements in natural resource management in these intensive integrated crop-livestock systems.

Okike et al. (2000) studied the adoption of improved cowpea varieties by different wealth groups of farmers.[20] Wealth ranking was done by members of the community, and three groups were distinguished.

1. Talakawa, poor masses, average gross farm output N76,000 or US$706 per household, average farm seize 3 ha. The total income is usually insufficient to provide food needs for the households of on average 8 persons. The Talakawa often constitute the main source for hired labour for the better endowed farmers. These people are supported by remittances from relatives and from proceeds from engagement in casual labour. This group constitutes 27% of the farmers' population.
2. Yan kiza-kiza, struggling middle class, 60% of the farmers are in this middle class. Crop harvest and sales of livestock and livestock products amounting to N110,000 (US$1,100) annually, provide enough to feed their family of nine persons all year round.
3. Mai-hali, the rich, gross income from farming on 14 ha of land averages N306,000 or US$3,060 per household of 10 persons per annum. They hardly involve members of their household in providing labour for farming, depending mostly on hired labour. People in this own many farms and produce for the market.

There was a significant increase in the adoption of improved cowpeas as wealth rank improved. Local and improved cowpea varieties contribute 11% and 12% respectively to gross farm revenue. But, improved varieties occupy only 13% of the cultivated area compared to 23% for local varieties. Thus the value of improved varieties output per unit of land is double that of local varieties. Of the respondents 45% used insecticide sprays. Farmers in the middle class invested as much as N5,500 per hectare per annum in insecticide sprays, compared to N1,300 per hectare per annum for both the poor and the rich. This study showed that the potential for adoption of improved dual-purpose varieties like IT90K-277-2 is high in all domains. The greatest potential for adoption is in the middle class, and they should get the bulk of attention.

Tarawali et al. (2000) note that the apparent popularity of cowpea, notwithstanding the low grain yields in farmers' fields, is probably related to the fact that cowpea is a legume with the potential for multiple contributions not only to the household food

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[20] Okike, I., P. Kristjanson, S. Tarawali, B.B. Singh, R. Kruska and V.M. Manyong. 2000. Potential adoption and diffusion of improved cowpea in the dry savannas of Nigeria: an evaluation using a combination of participatory and structural approaches. Paper presented at the World Cowpea Research Conference. III, 4-7 September 2000, IITA, Ibadan, Nigeria.

production, but also as a cash crop (grain and fodder), livestock feed and soil ameliorant.[21] In this context they consider that cowpea is a crop that may have a wide role in contributing to food security, income generation and the maintenance of the environment for the millions of small holder farmers who grow it in the region.

The authors note that in West Africa there is and will be an increasing demand for agricultural products, both crop and livestock. One of the responses of farming systems in the region to agricultural intensification is crop-livestock integration. Fallow periods have become reduced or absent and consequently the demand for nutrient inputs is raised; manure becomes more important. At the same time, as the livestock keepers increase their animal numbers, crop residues from the crop farmers become increasingly the major feed resource because there is no longer marginal or fallow land for grazing. In the dry savannas of West and Central Africa crop livestock integration is already a common feature of the farming systems, and it will increase further.

Whilst the benefits of crop-livestock are recognized, it is apparent that the food demands of the expanding population place increased pressure on these systems to raise productivity. Such increased productivity needs to be achieved without damaging the natural resource base if they are to be sustainable. Farmers are aware of the positive role of cowpea for soil fertility as they usually rotate the legume and cereal rows in alternate years.

Feeding cowpea fodder as a supplement increases animal weight during the dry season. Indications are, that from 1 ha of improved cowpea a farmer could benefit by an extra 50 kg of meat per annum from animals being better nourished, with over 300 kg more cereal grain as a result of improved soil fertility directly from the cowpea and more/better manure from the animals. There are other potential benefits, better fed ruminants will give more milk, and better fed traction animals will work better, meaning more and timely land preparation and better crop yields. The key component in all this is improved dual purpose cowpea varieties, as discussed earlier in this report.

Whilst the analysis of the FAO statistics showed a limited increase in cowpea yields in the region over the last 40 years, the above discussed studies show nevertheless that improved cowpea varieties have been adopted quite extensively by farmers in the region. Thus, the improved technologies meet the farmers' needs to a certain extent. Improved dual purpose cowpea varieties, new planting patterns of cowpea and cereals, as well as effective crop/livestock integration will most probably play an increasingly important role in agricultural development in the dry regions of West and Central Africa in the coming years. Effective pest management is only highlighted in the study concerning Ghana, however it will stay one of the major challenges for cowpea research in the future.

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[21] Tarawali, S.A., B.B. Singh, S.C. Gupta, R. Tabo, F. Harris, S.Nokoe, S. Fernandez-Rivera, A. Bationo, V.M. Mayong, K. Makinde and E.C. Odion. 2000. Cowpea as a key factor for the a new approach to integrated crop-livestock systems in the dry savannas of West Africa. Paper presented at the World Cowpea Research Conference. III, 4-7 September 2000, IITA, Ibadan, Nigeria.

5. Non-formal technology transfer

Given the lack of effectively functioning formal technology distribution systems in many countries in the region, opportunities for the transfer of technologies through non-formal channels merit to be exploited. Direct involvement of farmers in technology distribution will be a key element for future development in the region. At least as long as the private sector is not adequately organized to meet the farmers' demands in a reliable and economically acceptable manner. In the following, three examples of farmer to farmer seed production and distribution are presented. They show that excellent results can be achieved with this approach.

A good example of farmer to farmer seed distribution is the spread of improved cowpea varieties in Kano State, Nigeria. In Northern Nigeria cowpea is an important multi-purpose crop as shown earlier in this report. However the private seed industry is relatively poorly organized and has shown little interest in the marketing of improved cowpea varieties. Farmer to farmer distribution was considered as a possible option to introduce improved cowpea materials.

A project was initiated in 1997 jointly by IITA and the Kano State Agriculture and Rural Development Authority (KNARDA) to promote farmer production and distribution of improved seeds. Each selected farmer was given 3kg breeder seed of the improved cowpea cultivar IT90K-277-2, on credit to be recovered after harvest. Following farmer selection of improved cowpea materials IT90K-277-2 had been identified as one of the most promising new varieties. A total of 36 farmers (primary farmers) participated in 1997 in the project and produced 6,786 kg of seed. They sold most of the seeds to 262 farmers (secondary farmers) who had approached them on their own. This group of farmers in turn sold seeds of the improved varieties to the so-called tertiary farmers. Each year the primary farmers are provided anew with breeders seeds produced by IITA to ensure that the varietal purity is maintained. The details are presented in the following table 5. It should be noted that the contact with the farmers was maintained by a well experienced extension officer who has been detached from KNARDA to IITA.

Table 5. Farmer to farmer production and distribution of seed if the improved cowpea variety IT90K-277-2.

Year	Primary farmers (nb.)	Seed produced (kg)	Secondary farmers (nb.)	Seed produced (kg)	Seed produced by tertiary farmers (kg)	Total Seed Produced (kg)
1997	36	6,786				6,786
1998	51	6,224	262	11,800		18,024
1999	48	18,347	2,458	16,375	64,757	99,479
2000	100	46,250	6,916	173,133	34,847	254,240
2001	140	52,320	8,758	175,160	57,660	285,140

Some 30 kg of cowpea seeds are needed to plant one hectare. The 36 farmers were provided in 1997 with a total of 108 kg of seeds from which 3.5 ha could be grown. The total amount of improved seeds produced in 2001 can cover 285,140/30 = 9,500 ha. This represents a 3000 fold increase over four years and demonstrates clearly that a new variety that is well adapted to the farmers' needs, can be spread very effectively through farmer to farmer seed distribution.

The above example is based on traditional cowpea production during the rainy season. However, over the last decade there has been an increased interest by farmers in Northern Nigeria to grow cowpeas during the dry season under limited irrigation and on the flood recession areas. During the dry season cowpea suffers less from insect pressure and provides better returns than wheat produced in the irrigated areas. An improved cowpea variety (IT89KD-288) well adapted to the growing conditions in the dry season and meeting farmers' interests became available in early 1990s. In 1993 some 200 gram of breeder seed was given to one farmer, who multiplied it and sold it to other farmers. By 2000 over 10,000 farmers have planted this variety during the dry season and they produced over 4,000 ton of cowpea seed. This shows again that a new variety can be rapidly introduced by farmers. The yields during the dry season are in the range of 1-2 ton/ha and, consequently, the introduction of this new variety has brought the farmers substantial benefits. Traditional yields are generally well below 400 kg/ha.

Another example of farmer to farmer distribution of new varieties is the introduction of downy mildew resistant maize varieties in Ogbomoso in southwest Nigeria (S. Ajala et al. 2001).[22] The objectives of the exercise were to (i) rapidly disseminate downy mildew resistant varieties of maize in the area, (ii) develop a model that can be used directly or modified for similar deployment exercises elsewhere, and (iii) develop the capacity of farmers themselves to implement and maintain the intervention.

Nine villages were selected in 1997. Three farmers from each village were chosen and supported with seed, fertilizers, and guidance on how to produce seed. In the following season, each farmer backstopped in a different village three new farmers and another farmer in his own village with seeds and technical know-how imbibed from the earlier training. The following year, the number of villages participating in the exercise had increased to 25 and the number of farmers to 111. By the third year, 625 farmers in 159 villages were producing seed of resistant varieties and all had been trained on how to produce a healthy maize crop. Average yields increased by 50% from 1846kg/ha for non-participating farmers to 2763 kg/ha for participating farmers in 1998/99.

The end of survey conducted to obtain farmers perceptions of the project impact indicated that farmers observed a drastic reduction in the incidence of downy mildew within two years. This resulted in a yield increase for over 90 percent of the participating farmers. There was a significant increase in proportion of income attributable to downy mildew resistant maize. Further analysis revealed that the

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[22] Ajala, S.O., V.M. Manyong, V. Adenle, K.O. Makinde, A. Akintunde, J. Olufowote, M. Balaji and B. Bolayi. An approach to rapid development of agricultural technologies – The case of downy mildew resistant maize in Ogbomoso, southwest Nigeria.. Paper presented at Forth Biennial West and Central Africa regional Miaze Workshop, 14-18 May 2001, IITA, Cotonou, Benin.

additional income enabled farmers to finance children education, pay hired labour and expand farm sizes among others.

6. Introduction of improved maize and cowpea technologies in West Africa by Sasakawa Global 2000.

Introduction of improved maize technologies into West Africa has been undertaken since 1996 by Sasakawa Global 2000. Sasakawa Global 2000 encourages farmers to set up so-called management training plots of 0.25 ha each, and provides credit for the provision of inputs, i.e. seeds of improved crop varieties, fertilizers and pesticides. For maize the recommended amount of fertilizer to be used per hectare is a total of 135 kg of N, 45 kg of P, and 45 kg of K. About two third of the total N and all P and K is given as a basal dose, followed by a top dressing of 50 kg of N. These rates may vary somewhat from farmer to farmer. On cowpea the use of 100 kg NKP (15-15-15) per hectare is recommended, as well as two insecticide sprays. These inputs need to be repaid at the end of the cropping season. In Nigeria the programme was so successful that after three years there was no need anymore to provide credit at the beginning of the season.

A summary of the results obtained in Burkina Faso, Ghana, Guinea and Burkina Faso is presented in table 6. Very detailed data were received from the programme in Nigeria in particular with respect to production costs and net income per hectare for each of the participating farmers. A summary of these data is presented in tables 7, 8 and 9.

The data for maize in Burkina Faso, Ghana, Guinea and Mali show that the use of improved varieties and fertilizers increased the yields two to three fold compared to those obtained with traditional production practices. The data for cowpea are more limited but show also significant improvements in yield.

The data for Nigeria show without exception that excellent maize yields can be obtained in northern Nigeria, and that through the use of improved technologies average net income per hectare can be quite substantial. Maximum yields of some farmers were more than 8 tonnes/ha. These data clearly show that excellent yields can be realized with the available technologies, but to achieve this, farmers have to be assured that they will have access to the necessary production inputs. Traditional maize yields are in the order of 1200-1500 kg/ha, which means that farmers' gross income is normally less than $300/ha. The data for cowpea also show that farmers can benefit substantially from improved technologies. Gross income of farmers using traditional cowpea production practices is usually below $100/ha.

Table 6. Sasakawa Global 2000: introduction of improved maize and cowpea technologies in Burkina Faso, Ghana, Guinea and Mali.

Maize

Country	**Total ha**	**Yield (tonne/ha)**	**Range (tonne/ha)**	**Trad. yield (tonne/ha**
Burkina Faso				
1996	77.5	3.258		0.970
1997	170.25	2,293		1.181
1998	423.75	2.898		1.220
1999	485.5	2.601		1.115
2000	346,25	2.221		1.131
Ghana				
1997	223.75	3.65		1.53
1998	403.75	3.34		1.45
1999	228.50	3.90		1.45
2000	284.75	4.80		
Guinea				
1999	217	2.983		1.300
2000	273.5	2.62	4.5-1.0	1.600
Mali				
1998	250.25	2.434		1.175
1999	798.91	3.155	4.9-1.2	1.723
2000	84.50	2.725	6.4-1.3	1.952

Cowpea

Country	**Total ha**	**Yield (tonne/ha)**	**Range (tonne/ha)**	**Trad. yield (tonne/ha)**
Burkina Faso				
1998	14.5	0.778		0.541
1999	30	0.899		0.549
Ghana				
1997	67.25	1.56		0.62
1999	14.50	1.00		0.60
2000	41.25	1.58		

Table 7. Results of Sasakawa Global 2000 Maize Nigeria 1997 and 1998.

7.1 Sasakawa Global 2000 Maize Nigeria 1997

State/Zone	Area/zone (ha)	Yield range tonne/ha	Av. yield tonne/ha	Av. prod. cost/ha	Av. net income/ha
Kaduna					
Lere	155.45	9.3-2.3	5.6	$452.42	$690.19
Maigana	21.25	8.5-2.6	5.5	$422.62	$712.58
NAERLS	37.25	7.4-1.8	4.2	$297.30	$561.80
Samaru	15,00	6.9-1.7	4.1	$352.09	$492.38
Birnin Gwari	21.25	6.7-28	4.7	$408.29	$552.31
Kano	80.75	7.9-2.0	4.7	$374.46	$622.93
Jigawa	62.50	9.2-2.1	4.4	$409.88	$487.53
Katsina	7.50	7.2-1.6	4.3	$437.76	$429.23
Bauchi	0,75	5.4-3.8	4.8	$307.82	$680.76

Cost of 1 kg of maize in the market $ 0.20

7.2 Sasakawa Global 2000 Maize Nigeria 1998

State/Zone	Area/zone (ha)	Yield range tonne/ha	Av. yield tonne/ha	Av. prod. cost/ha	Av. net income/ha
Kaduna					
Lere	191.25	9.0-3,.3	6.1	$405.11	$741.23
Maigana	22.50	n.a.	6.2	$426.82	$327.76
Kano	108.75	8.2-2.2	5.2	$386.69	$599.47
Jigawa	61.00	6.4-2.9	4.7	$383.59	$499.40
Katsina	55.25	7.6-2.2	5.4	$355.36	$652.95
Bauchi	10.25	7.1-1.9	4.8	$302.40	$609.20
Gombe	24.75	6.0-3.3	4.3	$383.75	$419.39

Cost of 1 kg of maize in the market $ 0.19

Table 8. Results of Sasakawa Global 2000 Maize Nigeria 1999 and 2000

8.1 Sasakawa Global 2000 Maize Nigeria 1999

State/Zone	Area/zone (ha)	Yield range tonne/ha	Av. yield tonne/ha	Av. prod. cost/ha	Av. net income/ha
Kaduna					
Lere	201.25	8.2-4.0	6.0	$376.10	$264.27
Birnin Gwari	24.75	6.6-3.7	5.6	$328.15	$269.48
Samaru	13.00	6.3-3.9	5.0	$339.88	$200.62
Maigana	22.50	8.7-3.9	6.2	$374.02	$287.21
Kano	150.25	8.0-2.4	4.6	$274.66	$222.28
Jigawa	46.75	9.5-2.4	4.4	$315.44	$160.48
Katsina	116.75	12.6-1.6	5.5	$330.57	$275.60
Bauchi	56.55	9.4-3.5	4.7	$285.12	$217.15
Gombe	49,00	9.2-2.4	4.1	$305.09	$131.50

Cost of 1 kg of maize in the market $ 0.11

8.2 Sasakawa Global 2000 Maize Nigeria 2000

State/Zone	Area/zone (ha)	Yield range tonne/ha	Av. yield tonne/ha	Av. prod. cost/ha	Av. net income/ha
Kaduna					
Lere	214.25	13.9-4.3	6.5	$393.54	$377.84
Birnin Gwari	50.25	6.6-3.4	5.4	$388.23	$252.53
Maigana	33.00	8.0-2.4	5.3	$322.21	$309.37
Kano	150.00	7.4-2.4	4.9	$308.00	$465.89
Jigawa	68.25	7.2-1.6	4.7	$353.66	$387.30
Katsina	137.00	14.6-2.4	6.1	$290.12	$437.42
Bauchi	37.25	6.2-3.2	4.5	$275.29	$352.86
Gombe	44.75	6.0-2.8	4.1	$323.91	$227.71

Cost of 1 kg of maize in the market $ 0.12 in Kaduna and Katsina, $0.13 in Gombe, $0.14 in Bauchi, and $ 0.16 in Kano and Jigawa.

Table 9. Results of Sasakawa Global 2000 Cowpea Nigeria 1999, 2000 and 2001.

9.1 Sasakawa Global 2000 Cowpea Nigeria 1999

State	State (ha)	Yield range (tonne/ha)	Av. yield (tonne/ha)	Av. prod. cost/ha	Av. net income per ha
Kano	6.25	1.9-0.7	1.26	$106.23	$221.40
Jigawa	3.25	1.7-0.8	1.37	$147.74	$208.50
Bauchi	3.00	2.0-1.1	1.60	$120.32	$295.68

Fertilizer 100 kg NPK(15-15-15)/ha. Up to 2 insecticide sprays depending on pest infestation. Price of cowpea $0.26/kg

9.2 Sasakawa Global 2000 Cowpea Nigeria 2000

State	State (ha)	Yield range (tonne/ha)	Av. yield (tonne/ha)	Av. prod. cost/ha	Av. net income per ha
Kano	15.10	2.6-0.8	1.86	$123.10	$319.17
Jigawa	10.00	2.8-1.3	1.82	$150.10	$319.27
Bauchi	6.00	2.0-0.7	1.73	$136.37	$205.81

Price of cowpea per kg $0.20 at Bauchi, $0.24 at Kano and $0.26 at Jigawa

9.3 Sasakawa Global 2000 Cowpea Nigeria 2001

State	State (ha)	Yield range (ton/ha)	Av. yield (ton/ha)	Av. prod. cost/ha	Av. net income per ha
Kano	24.50	2.4-0.8	1.55	$118.73	$382.32
Jigawa	11.75	1.9-0.8	1.42	$155.66	$252.05
Gombe	5.75	1.4-1.1	1.21	$73.53	$253.75

Price of cowpea per kg $0.32 at Kano, $0.29 at Jigawa, and $0.27 at Gombe. At Gombe pesticides were not used.

7. Discussion and conclusions

It is evident, that the West and Central African region has its own international agricultural research requirements, because of its typical and varied agroecological and socio-economic conditions, and also because of the limited capacity of the national agricultural research systems. Four issues had to be addressed in this report. The first concerned the appropriateness of currently available technologies given the agroecological and socio-economic conditions in the region.

The review of relevant literature indicates that both maize and cowpea technologies have been adopted quite extensively by farmers in West and Central Africa. Maize research seems to have been most successful in this respect, and currently all the area planted to maize in the region is either occupied by improved varieties or by materials derived from them. The results obtained by farmers clearly show that the available improved maize and cowpea varieties can produce excellent yields, provided farmers have access in a timely manner to the necessary production inputs. Over the past 40 years maize has evolved from a subsistence crop to a food and cash crop. Originally maize was mainly grown in the humid forest zone, but the availability of well adapted germplasm has allowed it to become a major crop in the savannah zones, where growing conditions are more favourable for maize production. Consequently, the new maize technologies have affected in particular agriculture in these agroecological zones.

However, in the region as a whole maize and cowpea yields are still very low. The main reason for this seems to be the insufficient use of the necessary production inputs, in particular fertilizers. This affects very strongly agricultural productivity in this region where soil fertility is generally low and where pest pressure, especially for cowpea is high. There are a variety of causes for the very limited input use including inconsistent government policies, inadequate infrastructure, insufficient private sector development, and high costs of inputs. The harsh reality in West and Central Africa is that farmers must not only cope with difficult crop production conditions, but also with mostly ineffective government policies and actions, and very poor support services. Notwithstanding this almost total lack of support, farmers have adopted to a very significant extent improved varieties, especially in the case of maize. A significant benefit is that currently all maize grown in the region is resistant to the major diseases, and as such the introduction of the new materials has significantly increased production security.

The efficiency of the present technology transfer mechanisms in widely reaching the producers was the second issue to be addressed. The performance of technology transfer mechanisms in the region has been quite variable in effectiveness over time. The rapid spread of improved maize varieties in Nigeria in the 1980s was due to the successful operations of the Agricultural Development Projects. Adesina et al. (1997) discuss the positive role of the cotton development agencies in introducing improved maize production technologies in the dry savannas in francophone countries. Excellent examples are also available from other countries in the region. But, at present in West and Central Africa the agricultural extension systems are under-funded and often lack well motivated staff. Kristjanson et al. (2000) did not see a positive effect of extension staff visits on farmers' adoption of new technologies. It must be concluded that currently the traditional technology transfer mechanisms are not widely reaching the farmers. In this region also NGOs try to fill the vacuum, but with the exception of Sasakawa Global 2000 and a small number of in particular church related groups, it is too early to judge the overall benefits of their actions.

The third issue referred to the bottlenecks (technical, institutional, organizational and cultural) that restrain the generation, dissemination and adoption of improved technologies. In order for a technology to be of interest to farmers it has to fit well into his/her production practices. As mentioned in the report international agricultural research in West and Central Africa originally followed the green revolution approach. In a sense that is surprising because of the lack of a number of essential conditions required for the success of that approach. These include a favourable production environment, in particular through irrigation, and effective access to technical information and production inputs.

Much more progress might have been made if from the start of international agricultural research in the region, critical production constraints had been analyzed, and if solutions to address them had been undertaken in a more pragmatic manner. This would have meant that from the beginning of the establishment of IITA in the region more on-farm, applied research on effective production practices should have been undertaken, and less fundamental research on matters such as soil physical and chemical properties and plant physiology. But an applied approach to international agricultural research was for a long time not considered very positively within the CG system. It was felt that this type of research was the domain of the national agricultural research systems. This is fine for the CGIAR as a whole, but it did not take into consideration in an adequate manner the specific conditions and needs of agricultural research and development in West and Central Africa.

A more pragmatic approach might have led to a situation where the availability of more sustainable production technologies would have been more advanced than is currently the case. However, the fact remains that the unfavourable socio-economic circumstances in the region would still have impacted in a negative manner on agricultural productivity.

The institutional problems are well known in the West and Central African region. National agricultural research and extension structures, in almost all countries are severely under-funded. There is a significant number of well qualified staff but they lack adequate operational funds to carry out their work effectively. From an organizational point of view it will be important to further strengthen the ongoing collaboration between international and national agricultural research institutions. The national systems can, for example, draw significant benefits from collaborative projects through which they can complement their limited resources. At the same time, international research will be able to better focus on matters of direct interest to national systems.

Cultural differences in the region do not seem to have a marked effect on farmers' interest and capabilities to adopt new technologies. Provided that it can be clearly proven that a new technology fits into farmers' production practices and brings substantial benefits, without increasing production risks, it will usually be considered with interest by the farmers.

Opinions will most probably differ significantly on the implications for agricultural research of (i) agricultural developments over the last 40 years, and (ii) current socio-economic conditions in West and Central Africa (the forth issue to be addressed). Without doubt there will continue to be a strong need for research aimed at increasing crop productivity and ensuring that natural resources and production inputs can be used most effectively. Research on sustainable production systems will remain a key element in this. This will require close collaboration between plant breeders and natural resource ma nagement specialists. Natural resources must be considered in the broad sense, i.e. it must also involve extensive pest management research. Labour productivity must be increased to reduce production costs and augment production efficiency. It might be worthwhile to analyze the type of research needed to try to overcome the shortcomings of insufficient government support. This might lead to the conclusion that more efforts should be undertaken to strengthen farmer organizations.

A critical problem is also the remuneration that farmers receive for their products and this will require further research on effective farm product storage, transformation, and commercialization. As noted earlier all these issues need to be addressed in a pragmatic manner by working closely with farmers in order to fully understand their needs. In the current situation in West and Central Africa this does not require a great deal of fundamental research. The agricultural development problems are of a very practical nature and need solutions accordingly. It has sometimes been argued that the more applied agricultural research should be undertaken by the national systems. Research must be undertaken in effective partnership with the national colleagues, and this means that both should be working on the full range of research problems.

Poverty as defined by the international development community is very widespread among the rural population of West and Central Africa. Reduction of poverty is a major goal of the CGIAR. The data presented in this report in relation to the activities promoted by Sasakawa Global 2000, show that farmers can earn a net income from improved maize production in the order of $200 to $600 per hectare per year. About similar incomes might be generated by effective cowpea production. These results are obtained by maize farmers that produce 4 to 6 tonnes of maize per hectare. These are good maize yields given the overall production circumstances in the region.

In West Africa the amount of arable land available per capita of the rural population is about 0.4 hectares, or some 4 hectares per family. It might therefore be speculated that the average farmer, when using effective maize production practices, could earn between $800 to $2400 per year. This would have been a very decent income in a country like the Netherlands some 50 years ago. But if the average family size is eight persons and the poverty level is one dollar per person per day, than the average family must have a minimum annual income of $2920. Thus, given the current socio-economic conditions in West and Central Africa, there is little hope that significant numbers of farmers will be able to raise their income above the poverty line in the near future.

The one dollar a day figure might not be applicable in the same manner to all regions. In the study of Okike et al. (2000) farmers were considered rich by their own community if they had a gross annual income from farming of $3,060 per household of ten. Nevertheless, it can be concluded that farming will have to be diversified and farm size will have to be increased to become a remunerative activity in the region.

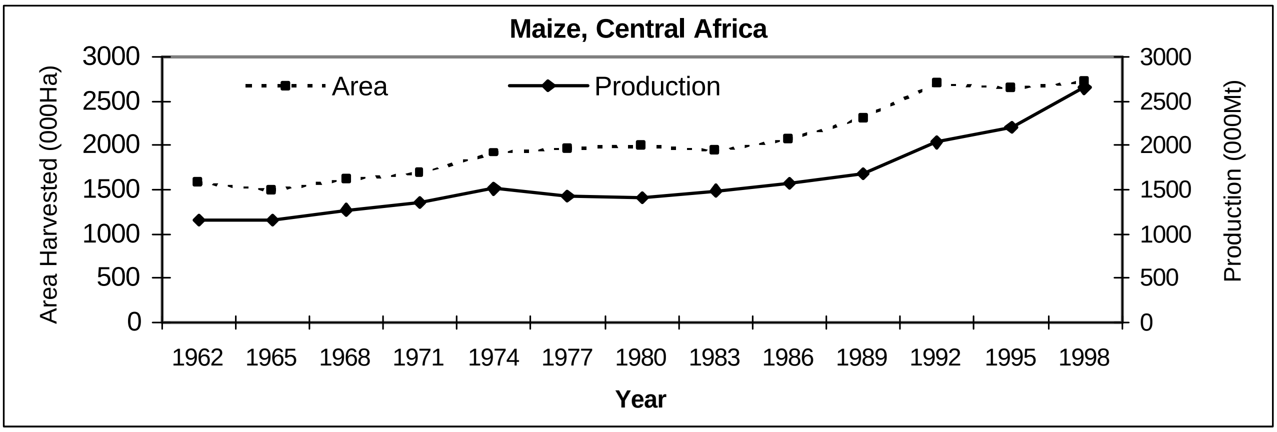
Annex I. Land use, population and production data for West and central Africa according to FAOSTAT Production Statistics 2002.

Figure 1. Land use and population development in Central Africa (three year averages).

Central Africa	Land use		Population		Area harvested to annual crops (1000 ha)
Year	Arab&perm crops (1000ha)	Arable land (1000ha)	Total (1000)	Agr. pop. (1000)	
1962	20,933.67	19,069.67	33,240.33	27,248.00	8,369.76
1965	21,348.33	19,328.33	35,600.33	28,749.67	8,320.52
1968	21,796.67	19,661.33	38,336.00	30,492.33	8,825.23
1971	22,184.67	19,919.67	41,232.33	32,230.67	9,368.97
1974	22,703.67	20,166.00	44,274.67	33,858.00	9,875.94
1977	23,422.00	20,627.00	47,909.67	35,818.00	10,190.03
1980	23,916.33	20,991.67	52,206.00	38,172.67	9,803.35
1983	24,187.33	21,047.33	57,084.33	41,018.00	9,689.90
1986	24,526.00	21,176.00	62,438.67	44,110.00	10,164.96
1989	24,627.00	21,258.67	68,380.66	47,470.67	10,906.16
1992	24,852.00	21,488.67	75,756.66	51,404.00	12,179.10
1995	24,997.67	21,628.67	83,674.34	55,311.33	12,529.86
1998	25,087.00	21,733.00	90,611.66	58,276.00	12,868.87

Figure 2. Maize production Central Africa (3-year averages).

Year	Maize, Central Africa		
	Area Harvested (000Ha)	Yield (Kg/Ha)	Production (000Mt)
1962	1583	733	1161
1965	1499	773	1159
1968	1616	791	1279
1971	1689	807	1362
1974	1919	791	1517
1977	1971	724	1428
1980	2001	707	1415
1983	1944	767	1490
1986	2064	763	1575
1989	2311	726	1678
1992	2702	753	2035
1995	2642	833	2200
1998	2720	974	2650



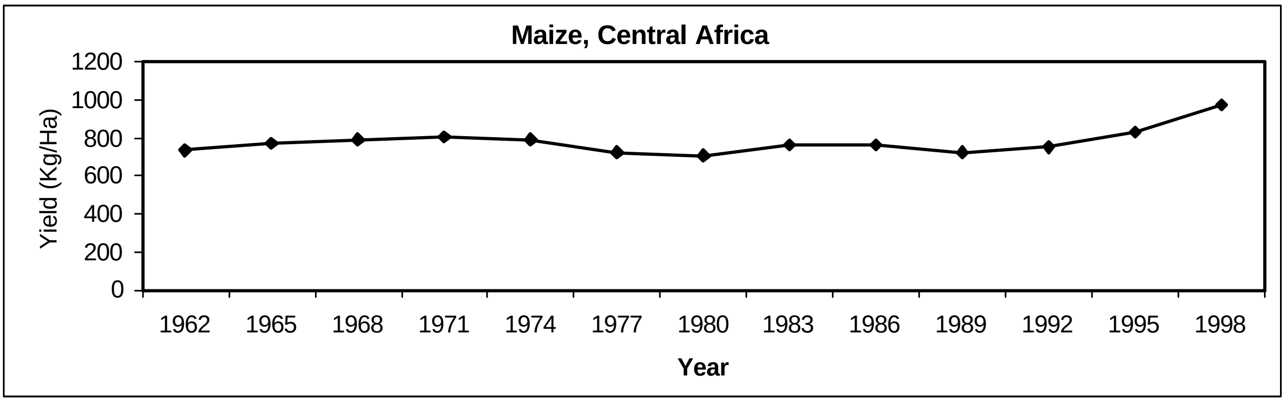
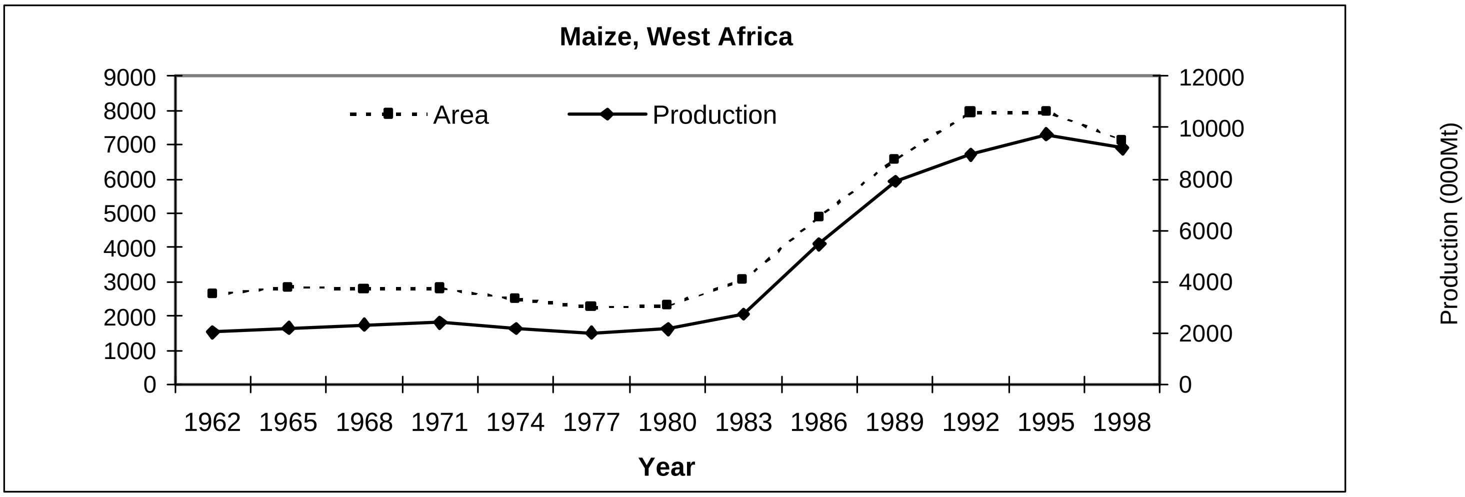


Figure 3. Land use and population development in West Africa (three year averages).

West Africa	Land use		Population		Area harvested to annual crops (1000ha)
Year	Arab&perm crops (1000Ha)	Arable land (1000Ha)	Total (1000)	Agr. pop. (1000)	
1962	48,820.00	42,767.33	79,137.34	61,692.67	32,202.93
1965	49,547.67	43,228.67	85,143.00	65,693.00	35,045.08
1968	50,339.33	43,882.67	91,769.34	70,095.34	38,345.87
1971	51,358.00	44,743.33	99,081.34	74,114.00	37,753.66
1974	51,759.33	44,877.00	107,273.70	76,864.66	36,584.66
1977	53,877.67	46,521.67	116,852.30	80,006.00	32,640.29
1980	55,243.67	47,640.67	127,739.00	83,496.66	30,879.70
1983	56,655.67	48,821.33	139,586.30	88,065.34	32,944.24
1986	58,429.33	50,287.67	152,481.30	92,922.00	39,895.63
1989	60,461.67	51,880.00	166,387.30	97,794.00	47,344.21
1992	62,340.67	53,447.33	180,946.70	102,397.00	57,168.34
1995	65,706.66	56,109.33	196,252.00	106,780.00	61,884.61
1998	66,406.34	56,478.33	212,611.00	111,127.30	66,184.85

Figure 4. Maize production in West Africa (three year averages).

Year	Maize, West Africa		
	Area Harvested (000Ha)	Yield (Kg/Ha)	Production (000Mt)
1962	2638	777	2049
1965	2844	774	2200
1968	2803	830	2325
1971	2808	862	2419
1974	2497	878	2191
1977	2253	892	2010
1980	2304	933	2150
1983	3045	901	2743
1986	4900	1117	5474
1989	6561	1208	7923
1992	7951	1125	8948
1995	7953	1224	9736
1998	7122	1292	9199



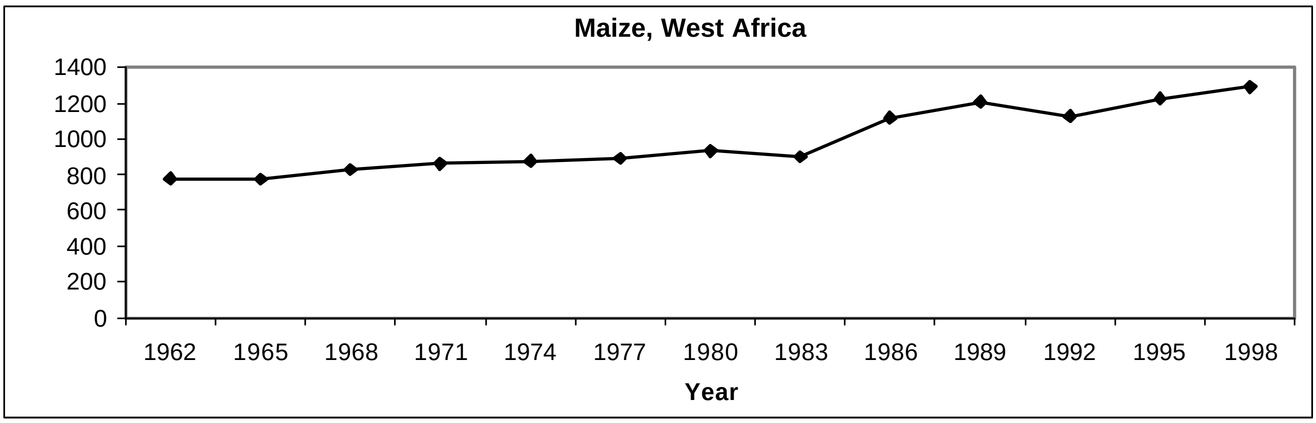
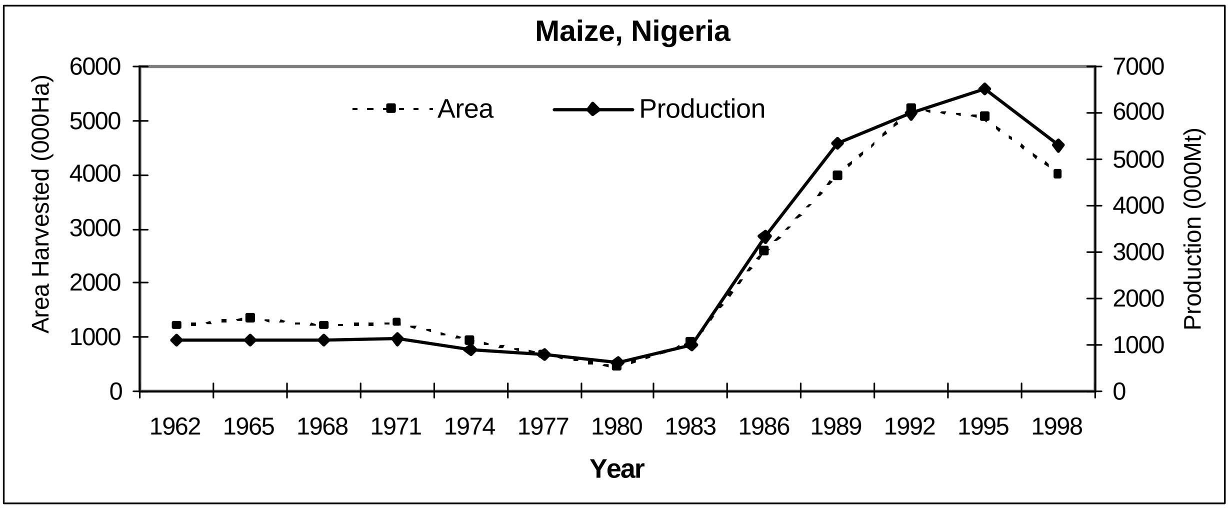


Figure 5. Maize production Nigeria (three year averages).

Year	Maize, Nigeria		
	Area Harvested (000Ha)	Yield (Kg/Ha)	Production (000Mt)
1962	1212	898	1088
1965	1340	809	1084
1968	1210	918	1110
1971	1261	887	1119
1974	932	954	889
1977	674	1176	792
1980	443	1370	607
1983	888	1122	996
1986	2588	1286	3329
1989	3969	1348	5348
1992	5225	1145	5980
1995	5057	1285	6500
1998	4016	1316	5286



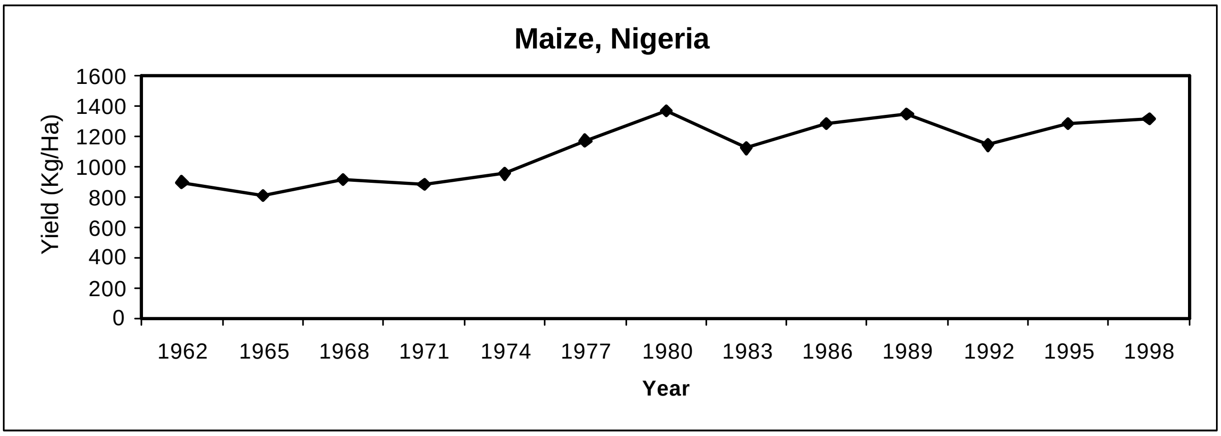
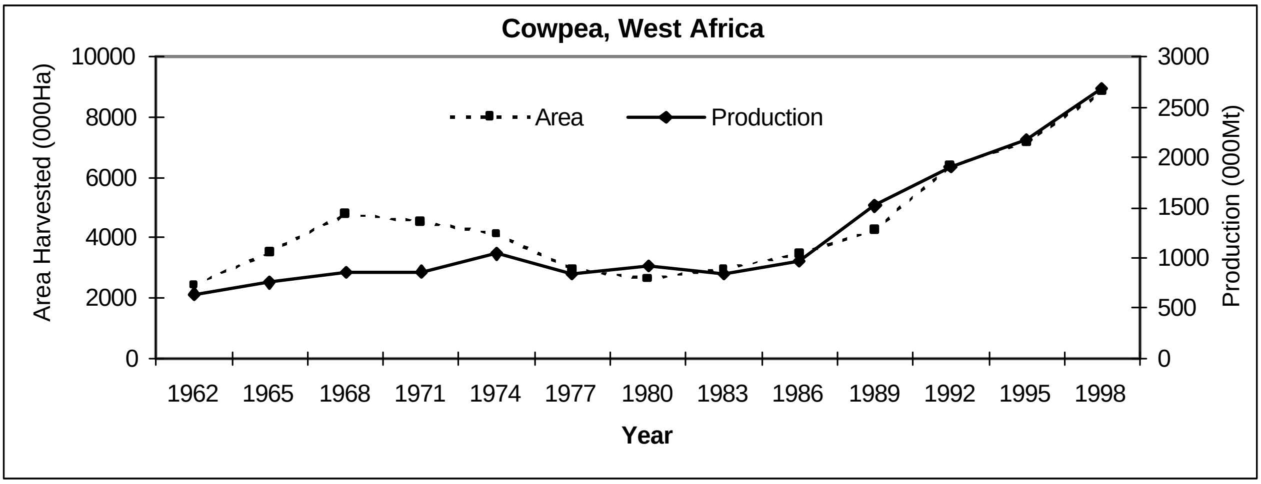


Figure 6. Cowpea production West Africa (three year averages).

Year	Cowpea, West Africa		
	Area Harvested (000Ha)	Yield (Kg/Ha)	Production (000Mt)
1962	2433	264	642
1965	3515	214	754
1968	4810	179	860
1971	4544	190	863
1974	4132	252	1040
1977	2957	285	842
1980	2645	348	921
1983	2972	286	848
1986	3469	281	974
1989	4269	357	1522
1992	6397	298	1907
1995	7168	303	2172
1998	8851	304	2688



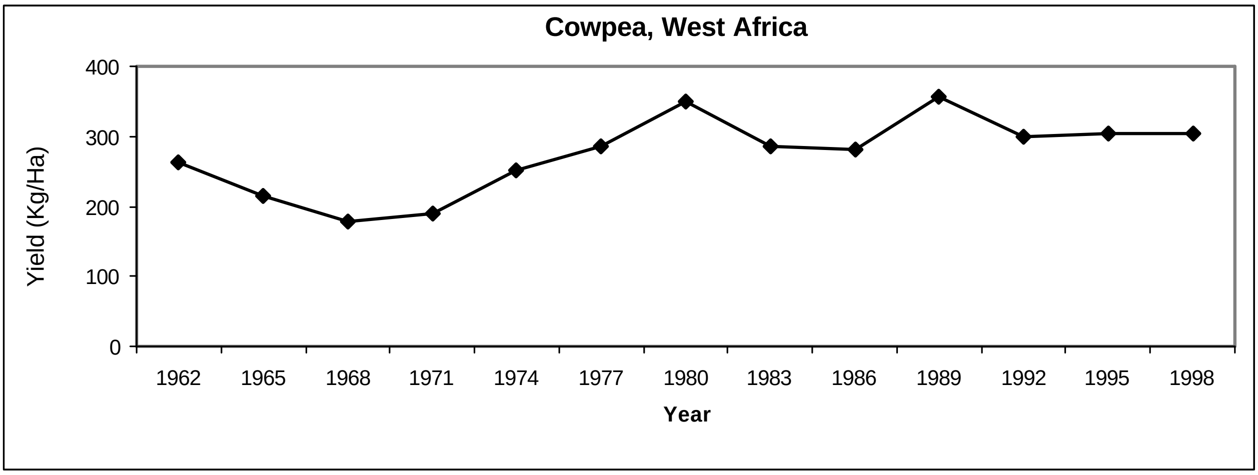
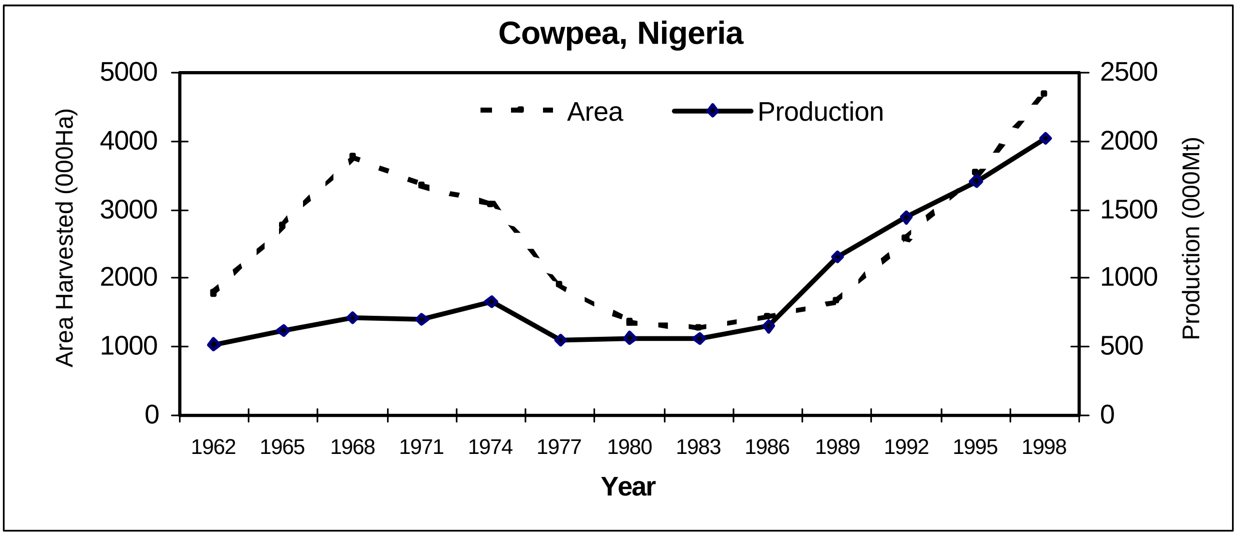


Figure 7. Cowpea production Nigeria (three year averages).

Year	Cowpea, Nigeria Area Harvested (000Ha)	Yield (Kg/Ha)	Production (000Mt)
1962	1776	291	517
1965	2772	221	614
1968	3783	188	710
1971	3358	208	698
1974	3075	269	828
1977	1893	288	544
1980	1347	419	565
1983	1270	440	559
1986	1435	451	647
1989	1663	696	1158
1992	2581	560	1446
1995	3538	485	1714
1998	4695	431	2024



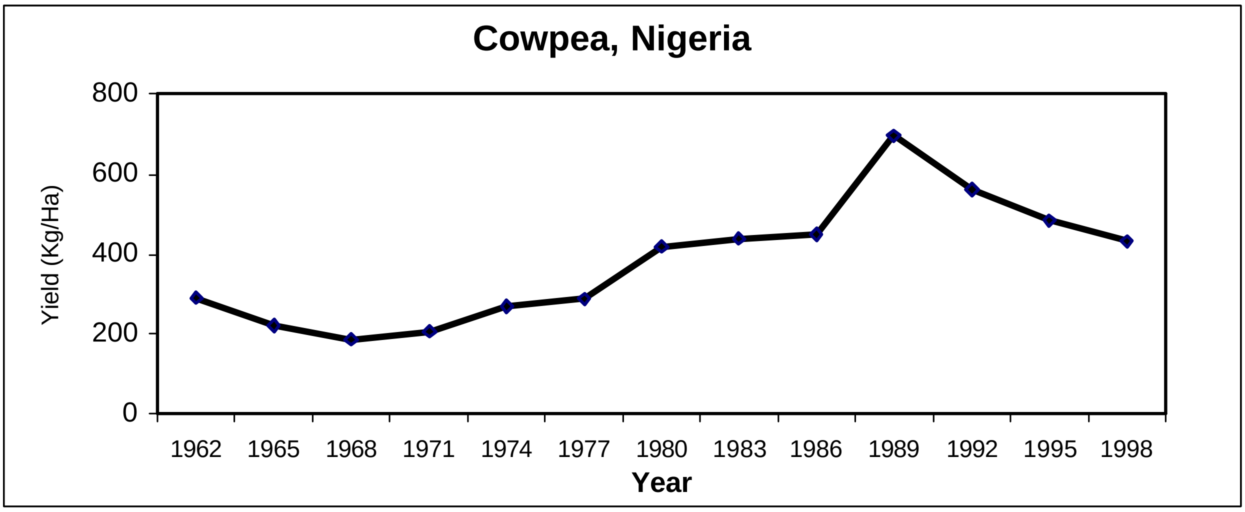


Figure 8. Cowpea production Niger (three year averages).

Year	Cowpea, Niger		
	Area Harvested (000Ha)	Yield (Kg/Ha)	Production (000Mt)
1962	469	145	68
1965	532	144	77
1968	801	98	78
1971	967	104	100
1974	863	171	148
1977	851	272	231
1980	1088	259	282
1983	1478	154	227
1986	1649	122	202
1989	2237	125	280
1992	3259	97	317
1995	3153	106	335
1998	3621	131	474