Maize revolution in West and Central Africa: An overview

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Abstract

Maize (*Zea mays* L.) is cultivated under a broad range of climatic conditions in West and Central Africa (WCA). Unfortunately, maize production is constrained by a host of abiotic and biotic stresses, including drought, low soil fertility, diseases, insect pests, and the parasitic weed *Striga hermonthica*. The stresses, which occur in all countries of WCA, are too formidable for individual national research programs to overcome. The West and Central Africa Collaborative Maize Research Network (WECAMAN) was inaugurated to develop and disseminate to farmers technologies that would overcome the production constraints. The technologies were developed in specific lead countries as well as IITA and evaluated in the relevant ecological zones of all WCA countries. The individual countries adopted the technologies that were suitable for their specific situations. Trends in land area under maize, total maize production, and yield per unit land area have shown dramatic increases in most of the WECAMAN member countries. Total maize production in the subregion has increased from about 2.74 million tons in 1980 to 10.5 million tons in 2000, a 384% increase. Maize production has caught up with, or surpassed sorghum and millet in much of the savanna areas of WCA. Apart from its use as human food and livestock feed, maize has become an important raw material for the flour milling, brewing, pharmaceutical, and starch-making industries in the subregion.

Résumé

Le maïs (*Zea mays* L.) est cultivé dans des conditions climatiques très variées en Afrique de l'Ouest et du Centre (AOC). Malheureusement la production du maïs est affectée par beaucoup de facteurs biotique et abiotique tels que la sécheresse, la faible fertilité des sols, les maladies, les insectes ravageurs, et les plantes parasites *Striga hermontica*. Les stress qui surviennent sur le maïs dans tous les pays de l'AOC sont très redoutables pour que le programme national de recherche d'un pays individuel puisse les surmonter. Le réseau collaboratif de recherche sur le maïs en Afrique de l'Ouest et du Centre (WECAMAN) a été créé afin de développer et de diffuser aux producteurs des technologies qui surmontent les contraintes de production. Les technologies ont été développées dans des pays spécifiques (centres leaders) et à l'IITA et évaluées dans les zones écologiques pertinent de tous les pays de l'AOC. Les pays ont adopté individuellement les technologies adaptées à leurs conditions particulières. Les tendances des superficies cultivées en maïs, la production totale du maïs et les rendements par unité de surface ont montré une augmentation dramatique dans beaucoup de pays du WECAMAN . La production totale du maïs dans la sous région a augmenté de 2,74 millions de tons en 1980 à 10,5 millions de tons en 2000, soit une augmentation de 384%. La production du maïs a rattrapé ou dépassé la production du sorgho et du mil dans beaucoup de zones de savane en AOC. A part son utilisation dans l`alimentation humaine et du bétail, le maïs est devenu une matière première pour les moulins à farines, les brasseries, les industries pharmaceutiques et de fabrique d`amidon dans la sous région.

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops in the countries of West and Central Africa (WCA). The importance of maize in human diet, livestock feed and as raw material for some industries has increased rapidly in the last two or three decades of the 20th Century.

Although maize was introduced to Africa, the crop rapidly gained popularity as a major food item as well as an intra- and inter-country trade commodity in the WCA subregion. Recognizing the enormous potential as a food crop, the countries in the subregion established maize research programs to improve the productivity of the crop. The maize scientists in the national agricultural research systems (NARS) in the subregion have on their own conducted on-station research in plant breeding, crop protection, crop management, postharvest technology, and utilization.

Maize research in some WCA countries has received several major boosts from direct and indirect foreign support. The establishment in 1967 of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria is perhaps the largest international boost to sustained, long-term maize research work in WCA. IITA initiated maize research activities around 1970 and, in collaboration with the national scientists, has made giant strides in developing high-yielding, disease-resistant varieties adapted to the different agroecologies in WCA. CIMMYT, in collaboration with the NARS of some WCA countries, also conducted maize research in the subregion. Over the years, both NARS and international scientists, working individually and collaboratively, have developed many maize production technologies. CIMMYT maize germplasm has been particularly useful in the development of improved varieties for WCA.

During the last four decades of the 20th century, large investments went into maize research and development in WCA from national governments and international donor agencies. Apart from IITA, the West and Central Africa Maize Collaborative Research Network (WECAMAN) was established during the period. USAID has continued to provide financial support for collaborative maize research in WCA, initially through the Semi-Arid Food Grain Research and Development (SAFGRAD) Project and later through WECAMAN. Although the management of WECAMAN is by the NARS of the member countries, IITA has been the executing agency. At present, the maize activities of WECAMAN cover all the ecological zones of the eleven member countries including Bénin, Burkina Faso, Cameroon, Côte d'Ivoire, Ghana, Guinea, Mali, Nigeria, Senegal, Tchad, and Togo.

Maize production in WCA has been greatly constrained by many abiotic and biotic stresses too formidable for individual NARS to combat single handedly. Most of the constraints cut across the countries in similar ecological zones. Examples of such constraints are the maize streak virus disease, infestation by the stem borer complex and the parasitic weed *Striga hermonthica*, drought, and low soil nitrogen. The networking approach has been effectively used to solve the problems and increase maize production. Herein, we present an overview of the impact of networking on maize productivity and production in the subregion.

Methodology

The networking approach adopted by WECAMAN has been described in greater detail elsewhere (Badu-Apraku *et al.*, 2002) and are presented briefly herein.

One reason for the delay in exploiting the potential of the savanna ecological zone as the grain belt of WCA (Kassam *et al.*, 1975) was the lack of improved maize varieties specifically adapted to the ecology. In 1980, IITA initiated maize research activities in the northern Guinea savanna of Nigeria. Results from the research provided benchmark information for WECAMAN activities. WECAMAN's approach to solving the problem was to concentrate on the development of technologies specifically adapted to the savannas. At the initial years of the network, much of the efforts were concentrated on breeding and agronomic research. NARS programs that were strong in some specific areas of research were identified and used as lead centers for generating technologies in the respective subject-matter areas. For example, the Cameroon and Ghana national programs were relatively strong in breeding and were, therefore, the lead centers for specific breeding projects funded by the network. Technologies emanating from the lead centers as well as from other researchers were evaluated in all member countries. This approach promoted collaboration among national and international scientists in the subregion to develop, test, and transfer to farmers' high yielding and adapted maize cultivars.

Regional uniform variety trials (RUVT) were used as the vehicle for testing the performance of elite varieties under different environmental and socioeconomic conditions and for the direct exchange of varieties and source germplasm among countries. Candidate varieties for the RUVTs are elite varieties emanating from the Network Coordinator's resident research, international research stations, and national programs of member countries in the subregion. The goal of the RUVTs is to afford national scientists the opportunity to identify varieties for broad or narrow adaptation, as appropriate for their individual situations. RUVTs provide breeders in the national maize programs useful information on the performance, adaptation, yield stability, disease and pest resistance, agronomic characteristics, and end-use quality attributes of the elite maize varieties and source germplasm. Maize scientists in the member countries have been able to identify and select from the RUVTs high-yielding and well-adapted varieties for further testing and release in their countries.

For many years, the Food and Agricultural Organization (FAO) of the United Nations in Rome has been keeping an agricultural database for the WCA subregion. For the purposes of this report, we summarized the data on land area, total production and yield per hectare for maize and compared with those for sorghum and millet from 1980 to 2001 across all WECAMAN member countries. The data were also summarized individually for the eight member countries that had been on the network consistently since inception. Linear and quadratic models were used to determine the trends and approximate values of the three variables. The regression analyses were done using the Curve Estimation Mode of the Regression Procedure in SPSS 7.5 for Windows.

Results

Land areas planted to maize, millet, and sorghum from 1980 to 2001 are presented in Figure 1. At the beginning of the period, significantly smaller land area was cultivated to maize relative to the other two crops in the subregion. From 1990 to 1995, land areas under the three crops were about equal, although that under maize again became significantly lower thereafter. Regression models revealed that the rate of increase in land area was similar for the three crops, about 0.28–0.29 million ha^{-1} per year (Table 1). Total land area under maize as estimated from the quadratic regression models is presently about 8.0 million ha; corresponding figures for millet and sorghum are 10.3 and 10.9 million ha, respectively.

Trends in total grain production (Fig. 2) were similar to those of total land area. For total grain production, however, the maize curve caught up with those of the other two crops in 1987–88 and has remained higher than millet and about the same as or slightly higher than sorghum since then (Fig. 2).

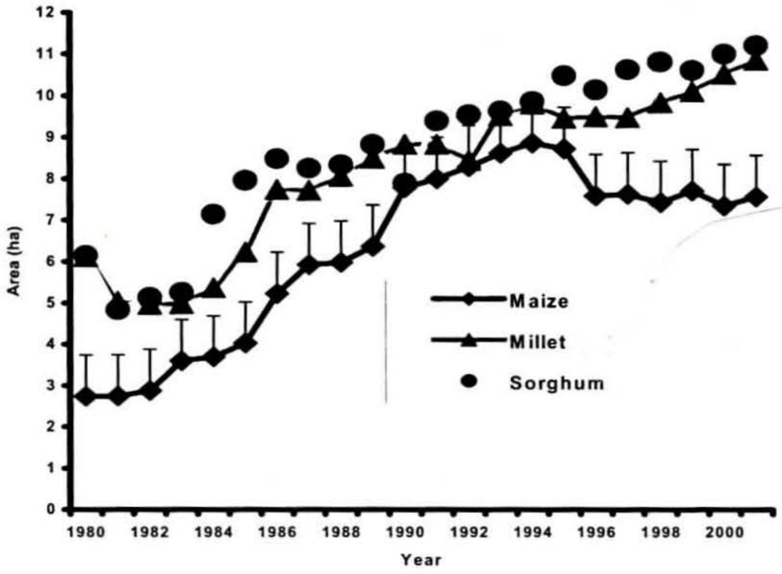

Figure 1. Total land area planted to maize, millet and sorghum in 11 West and Central African countries, 1980–2001. Vertical lines are standard errors.

Average annual increase in total production for maize (0.43 million tons) was much larger than the annual increases for millet and sorghum (0.23 and 0.30 million tons, respectively). Estimated total grain production in 2001 was 12.1, 9.5, and 11.6 million tons for maize, millet and sorghum, respectively (Table 1).

Average grain yield for maize in the subregion increased from about 0.9 t ha^{-1} in 1980 to about 1.3 t ha^{-1} in 2001, an annual increase of 0.02 t ha^{-1} (Fig. 3, Table 1). Grain yield of millet and sorghum remained more or less unchanged throughout this period.

Between 1980 and 2001, land area under maize increased significantly for all member countries except Cameroon and Mali (Table 2). The significant increases ranged from 36% for Burkina Faso to 440% for Nigeria. The quadratic model produced better fit for the Mali ($R^2 = 0.43$) and Cameroon ($R^2 = 0.28$) data. Land area under maize actually decreased in Cameroon between 1983 and 1991 before increasing slightly to a levelling off point.

Apart from Mali, all countries recorded significant linear increases in total grain production during the period under study (Table 2).

Table 1. Parameters from the regression analysis of total land area under maize (million ha), total grain production (million t) and grain yield (t ha-1) for maize, millet, and sorghum in West and Central Africa, 1980–2001.

Crop	Model	R^2,%	ΔR^2,%	$\hat{y}$
Land area under crop (million ha)				
Maize	$\hat{y} = 3.13 + 0.28x$	72**	–	9.01
	$\hat{y} = 0.76 + 0.89x - 0.026x^2$	92**	20**	7.98
Millet	$\hat{y} = 4.99 + 0.28x$	89**	–	10.87
	$\hat{y} = 4.27 + 0.46x - 0.008x^2$	91**	02ns	10.40
Sorghum	$\hat{y} = 5.41 + 0.29x$	89**	–	11.50
	$\hat{y} = 4.55 + 0.50x - 0.009x^2$	92**	03ns	11.08
Total grain production (million t)				
Maize	$\hat{y} = 3.11 + 0.43x$	85**	–	12.14
	$\hat{y} = 1.27 + 0.98x - 0.026x^2$	95**	10**	10.28
Millet	$\hat{y} = 4.59 + 0.23x$	92**	–	9.50
	$\hat{y} = 4.21 + 0.35x - 0.005x^2$	94**	02ns	9.12
Sorghum	$\hat{y} = 5.35 + 0.30x$	92**	-	11.60
	$\hat{y} = 5.28 + 0.32x - 0.001x^2$	92**	00ns	11.53
Grain yield (t ha-1)				
Maize	$\hat{y} = 0.92 + 0.02x$	74**	–	1.34
	$\hat{y} = 0.89 + 0.026x - 0.0003x^2$	75**	01ns	1.30
Millet	$\hat{y} = 0.77 - 0.002x$	05ns	–	0.81
	$\hat{y} = 0.77 - 0.002x - 0.000x^2$	05ns	00ns	0.81
Sorghum	$\hat{y} = 0.81 + 0.001x$	02ns	–	0.83
	$\hat{y} = 0.82 - 0.002x - 0.0001x^2$	03ns	01ns	0.82

** Significant at 0.01 level of probability; ns = not significant.

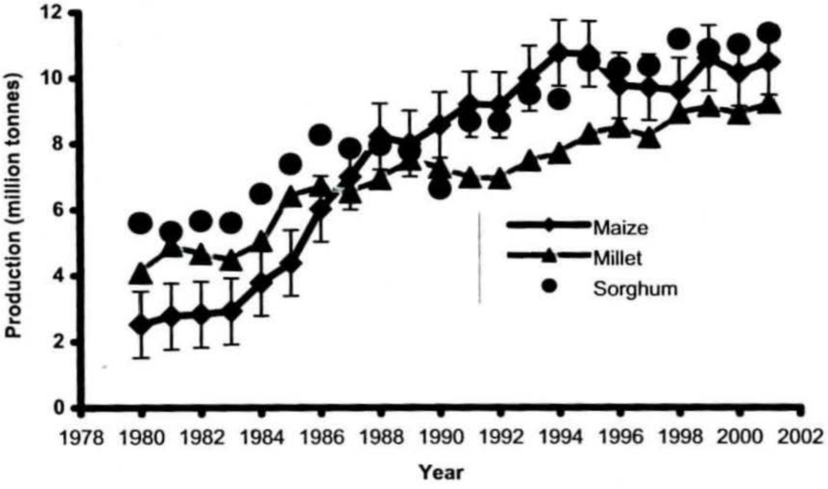

Figure 2. Total grain production (million tons) for maize, millet, and sorghum in 11 West and Central African countries, 1980–2001. Vertical lines are standard errors.

The annual increase ranged from about 12 000 t to 31 000 t for the countries with Nigeria recording 276 000 t increase per annum. Quadratic model produced a better fit for the Mali data (($R^2 = 0.60$), with the peak occurring in 1993–95.

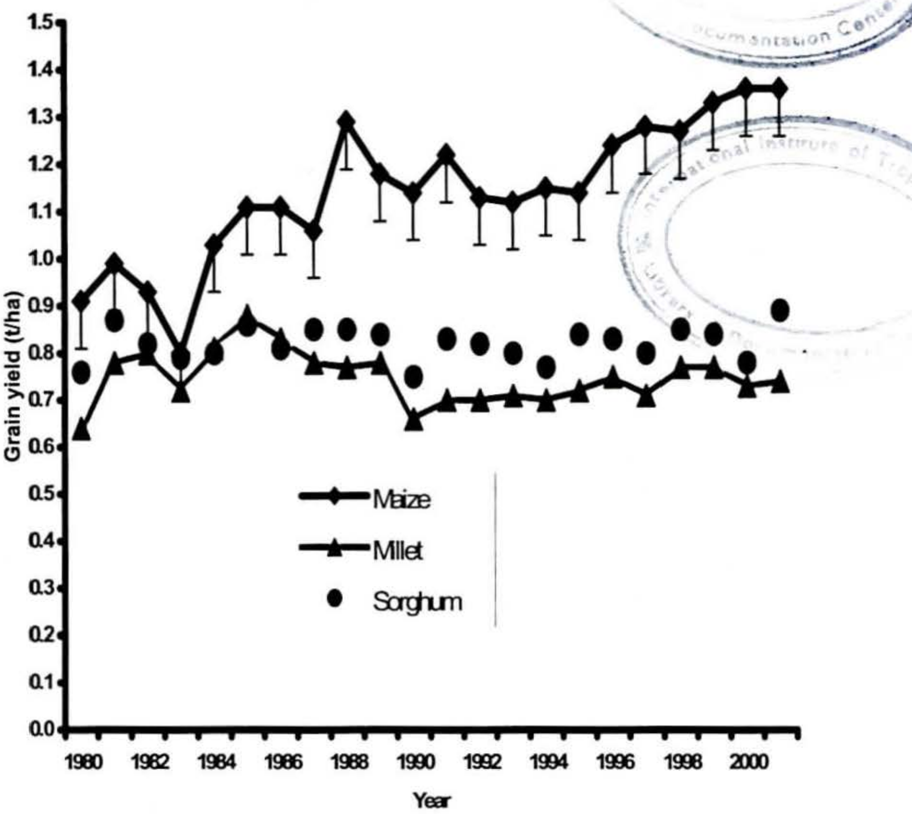

Figure 3. Average grain yield (t ha^{-1}) for maize, millet, and sorghum in 11 West and Central African countries, 1980–2001. Vertical lines are standard errors.

Grain yield per unit land area showed significant linear increases in only four of the eight countries (Table 2). The increases were particularly striking for Bénin and Ghana with linear b-values of 27 and 28 kg ha^{-1} per annum, respectively.

Although the linear increase for Cameroon was quite large (53 kg ha^{-1} per annum), the linear model accounted for only 46% of the total variation in grain yield per ha. The quadratic model produced a better fit with a positive quadratic b-value and an R^2 of 0.91

Discussion

An evidence for the occurrence of green revolution is a sustained, dramatic increase in crop yields. Scientists generally agree that such phenomenal increases in maize production are possible in the savanna zones, especially the Guinea savanna of WCA. Development and adoption by farmers of high yielding, disease and pest resistant maize varieties and crop production technologies specifically adapted to the various agroecologies and socioeconomic situations is central to the green revolution in WCA. Development of such varieties and technologies has been the preoccupation of WCA maize scientists in the last few decades.

Table 2. Parameters from the linear regression analysis of total land area under maize (million ha), total grain production (million t), and grain yield (t ha^{-1}) for maize in eight WECAMAN member countries (1980–2001).

Country	1980	2001	b-value	R^2,%
		Land area (million ha)		
Benin	0.38	0.57	0.009	76**
Burkina Faso	1.00	1.36	0.017	55**
Cameroon	0.33	0.35	0.001	00ns
Côte d'Ivoire	0.51	0.72	0.010	78**
Ghana	0.20	0.33	0.006	57**
Mali	0.48	0.80	0.015	28ns
Nigeria	0.99	5.34	0.207	50*
Togo	0.14	0.39	0.012	86**
All countries	**4.03**	**9.86**	**0.035**	
		Total grain production (million t)		
Benin	0.22	0.66	0.021	88**
Burkina Faso	0.61	1.26	0.031	61**
Cameroon	0.28	0.76	0.023	71**
Côte d'Ivoire	0.38	0.67	0.014	76**
Ghana	0.09	0.34	0.012	73**
Mali	0.43	0.70	0.013	42ns
Nigeria	1.00	6.80	0.276	67**
Togo	0.09	0.45	0.017	85**
All countries	**3.1**	**11.64**	**0.051**	
		Grain yield (t ha^{-1})		
Benin	0.64	1.21	0.027	83**
Burkina Faso	0.59	0.91	0.015	47 *
Cameroon	1.10	2.21	0.053	46 *
Côte d'Ivoire	0.72	0.89	0.008	22ns
Ghana	0.52	1.11	0.028	75**
Mali	0.91	0.91	0.000	00ns
Nigeria	1.28	1.30	0.001	00ns
Togo	0.79	1.13	0.016	39ns
All countries	**0.82**	**1.23**	**0.0196**	

*, ** Significant at 0.05 and 0.01 levels of probability, respectively; ns = not significant.

Summarized in Tables 3 and 4 are some of the technologies that have emanated from the research efforts, their sources and the countries that have adopted the technologies in the subregion. In addition to developing new technologies adapted to the subregion, the network organized, executed, coordinated and funded several maize production activities that contributed to the increased maize output. These are national maize workshops and annual planning sessions; regional uniform variety trials; on-farm demonstrations; training courses and workshops; enhancement of exchange of ideas and technical experience among NARS scientists; and promotion of community level seed production.

Table 3. Improved maize varieties transferred across countries among researchers or research systems and adopted by farmers through WECAMAN (1994–2000)

Improved variety	Countries adopting variety	Source of variety
DMR-ESR-Y	Cameroon, Mali, Tchad, Guinea	IITA
Ikenne 8149 SR	Togo	Togo/IITA
AB11	Togo, Nigeria	Togo
DMR-ESR-W	Bénin, Côte d'Ivoire, Cameroon	IITA
Pool 16 DT	Cameroon, Bénin, Togo Ghana, Côte d'Ivoire, Burkina Faso, Sénégal	WECAMAN
TZEE-W SR BC_5	Bénin, Côte d'Ivoire, Ghana, Cameroon Senegal, Tchad	WECAMAN WECAMAN
Maka SR	Burkina Faso	WECAMAN/ Mauritania
TZESR-W X Gua 314	Togo, Côte d'Ivoire, Nigeria	WECAMAN
CSP SR BC_5	Côte d'Ivoire	WECAMAN
TZEF-Y SR	Nigeria, Mali	WECAMAN
TZE Comp 4	Guinea, Tchad, Côte d'Ivoire, Senegal	IITA
Obatanpa	Mali, Benin, Ghana Burkina Faso, Togo, Cameroon, Nigeria, Senegal, Tchad	Ghana
95 TZEE-Y_1	Nigeria, Senegal, Tchad	WECAMAN
95 TZEE-W_1	Nigeria	WECAMAN

The network also used farmer participatory testing of varieties and crop management practices in addition to the adoption of the Production Test Plot (PTP) program to demonstrate new technology, strengthen research–extension–farmer linkages and train extension agents. These activities collectively formed the technological foundation of the maize-based green revolution in WCA. Impact studies in most of the member countries showed that maize was rapidly being adopted in many marginal areas because of the availability of early and extra-early maturing varieties with high yield, better taste, and high market prices. Generally in the subregion, maize technology adoption rate, social rate of return, and the social gains from maize research and extension have been positive.

Table 4. Improved cultural practices exchanged among WECAMAN countries through networking, 1994–2001.

Cultural practice	Developed by	Adopted by
Increased plant population for higher grain yield of early and extra-early varieties	Cameroon, Nigeria, Bénin	Ghana, Bénin, Togo, Nigeria Cameroon, Burkina Faso,
Earlier date of fertilizer application (top dressing) for increased yield of early and extra-early varieties	Bénin, Cameroon	Bénin, Togo, Ghana Cameroon, Burkina Faso
Use of maize-legume rotation to improve soil fertility and maize grain yield	Bénin, Ghana, Cameroon	Bénin, Ghana, Cameroon

The data analyzed herein are, at best, estimates obtained by FAO in the subregion and, unfortunately, we had no way of ensuring the accuracy of the data. However, results and conclusions of independent impact studies conducted in most of the member countries without reference to the data analyzed herein corroborate our conclusions (Laraba 2001; Phillip 2001; Sanogo *et al.* 2001; Manyong *et al.* 2000; Enyong *et al.* 1999).

Results of the impact studies clearly justified the investment in maize research, training and development activities in the subregion. The impact studies further showed that maize was quickly replacing sorghum in the diet and cropping systems of the rural dwellers. The rapid displacement of sorghum, the traditional staple food crop in the savanna of WCA, by maize was found to be linked to several factors, including mainly early maturity, high yield, better taste, high market prices, availability during hunger period and color (Enyong *et al.* 1999). Also, the impact studies showed that some of the countries in the subregion experienced high annual growth rates in maize production far above the 3% population growth observed for the subregion as a whole. Estimated annual growth rates in total maize production for the period covered in our study were Bénin 9.5%, Burkina Faso 4.7%, Cameroon 8.2%, Côte d"Ivoire 3.7%, Ghana 13.3%, Mali 3%, Nigeria 27.6%, and Togo 18.9%.

In addition, Manyong *et al.* (2000) observed that, on the average, adoption of improved maize varieties resulted in a yield advantage of 45% relative to local varieties in WCA. In our study, average yield per ha increased by about 50% in 2001 relative to 1980. Our study, however, showed that the increase resulted mostly from only four countries; that is, Bénin 89.1%, Burkina Faso 54.2%, Cameroon 100.1%, and Ghana 113.5%.

The relatively low yield per ha is of serious concern to maize researchers in WCA. Fakorede *et al.* (2001) attributed the increased total maize production in WCA to extensification rather than intensification. As noted by Fakorede and Akinyemiju (2003), little new land is available for agriculture in the WCA subregion. Therefore, extensification of agriculture will, at best, meet the food demand only in the short term; intensification will have to be pre-eminent in the long term.

The extensification of maize production currently leading to the maize-based green revolution has several advantages. First, it provides a feedback to the breeders that the varieties being developed are acceptable to the farmers in the subregion. The fact that there are adapted varieties for the savannas is the basis for the unprecedented extensification of maize production in the subregion. Second, farmers are gradually becoming aware of the differential response of crops to high-input agriculture. One of the reasons maize has been displacing sorghum and millet in the savannas is that farmers found that the improved varieties of maize had better response to fertilizer application than sorghum and millet. Third, extensification will ultimately lead to intensification of maize production. Because of the limited availability of new land for maize production, maize farmers will seek for and adopt improved production technologies to increase their maize output. An indication of this speculation occurred from 1996 to date when fertilizers were no longer readily available in the subregion. As shown in Figure 1, there was a reduction in the amount of land under maize whereas land under sorghum and millet continued to increase during this period. Total production and yield per ha for maize, however, continued to increase thus indicating a gradual shift to intensification of maize cultivation.

A full-blown maize revolution will be achieved when farmers practice intensive maize production. One important factor that has seriously constrained a full-blown green revolution is the gap between research and farmers' yields. Maize production environments in WCA are characterized by low external inputs, fragile soils with low moisture-holding capacity, and low nutrient and organic matter contents. Some of the factors responsible for the differences in yield between research and farmers' fields are weeds, pests, diseases, soil fertility, and crop management practices. Average yield in the subregion has only increased modestly from the long standing <1.0 t ha^{-1} to about 1.3 t ha^{-1}. Average yield in researcher managed trials is about 6 t ha^{-1}. As clearly shown by Fakorede (2001), yield obtained in researcher managed trials are in fact still far from the potential yield of maize in WCA. There is, therefore, the need to further intensify research and development activities.

The causes of yield gap have been studied to a limited extent in WCA (Carsky and Kling 1997; Fakorede *et al.* 2001). In general, low yields in farmers' fields were caused by low soil nutrient supply, damage by *Striga*, low plant density, late planting, late first weeding, and several other factors that constitute poor management practices. Realization of attainable maize yields must, therefore, combine appropriate variety, soil management and crop management practices.

Conclusion

Although increased maize production in the subregion resulted from the synergistic effort of many players, WECAMAN, in collaboration with IITA and CIMMYT, and unflinching financial support of the USAID, has been a central component of the team effort. Land area under maize, total maize grain production and, to a smaller extent, grain yield per unit land area increased dramatically from 1980 to 2001 for the WCA subregion. The annual growth rate for land under maize and total grain production was high for most individual countries. The increase in grain yield per unit land area was particularly striking for four countries in the subregion. Increase in total grain production was due primarily to extensification rather than intensification of agricultural practices. A full-blown maize revolution would occur when farmers in WCA practice intensive maize production.

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