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Contributions made by the CGIAR and its Partners to Agricultural Development in Sub-Saharan Africa

The attached paper on the contributions of the CGIAR to agricultural development in Sub-Saharan Africa was prepared by SPIA/TAC for the Sub-Saharan Africa Agricultural Research Day during MTM'01. It will be introduced by Dr. Guido Gryseels, Deputy Executive Secretary of TAC.

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CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

TECHNICAL ADVISORY COMMITTEE

Contributions made by the CGIAR and its Partners to Agricultural Development in Sub-Saharan Africa

A Report from
TAC's Standing Panel on Impact Assessment (SPIA)

TAC SECRETARIAT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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Foreword

In this document, TAC/SPIA presents available information on the contributions that the CGIAR, working with its partners in Africa and elsewhere, has made to agricultural development in Africa.

The paper was requested rather recently. Thus, SPIA had to rely on readily available documentation, which means that the review by necessity is incomplete and sometimes anecdotal in terms of describing the whole range of actual and likely contributions of the CGIAR. The paper does point out the serious need to develop a more systematic and comprehensive assessment of the impacts of the CGIAR and its partners in achieving the goals of reducing poverty, hunger and malnutrition. This is not a simple task that can be accomplished in a short timeframe. Going from numbers on the adoption of technologies to assessing impacts in a transparent, objective and comprehensive fashion is a major challenge, both in terms of methodology development and data generation.

In the case of the impacts of crop genetic improvement research in Africa, the assessment in aggregate has been made by Professors Evenson and Gollin based on studies carried out by scientists of the eight CGIAR crop centres, of their NARS partners, and of the countries that were the subject of the case studies. Extracts of this work with respect to sub-Saharan Africa are presented in the paper. Similar assessments of the aggregate impacts of the CGIAR remain to be done for other areas of CGIAR activity, for example related to policy, natural resources management, agroforestry, forestry, crop production systems, livestock and fisheries research, and for biodiversity conservation and scientific capacity strengthening activities of the System. A few available examples are presented, but the treatment is far from complete. One reason why these areas have lagged behind genetic improvement research is that the methodologies for assessing such impacts have not yet been adequately developed and tested; and in some cases, they are not available. Another reason is the lack of comprehensive time series and cross sectional data. TAC/SPIA is addressing these issues together with the CGIAR centres and the global impact assessment research community. Progress is being made but much remains to be done.

The main conclusions of interest that come out of this study are that:

- *the area of food crops planted with modern varieties has increased from 1% in 1970 to 26% in 1998 with half of this expansion occurring during the last decade;*
- *the CGIAR content in modern varieties is high in all the crops that have been studied. On average, half of modern varieties were based on a CGIAR cross, and an additional 25% had a CGIAR crossed ancestor;*
- *the contribution of genetic improvement to yields has been considerable, especially during the last decade. Average yields have increased substantially for wheat, maize, cassava, rice, cowpea and potato. Other crop yields have increased in individual countries;*

- *biological control of cassava mealy bug has provided very high returns on investments with a cost benefit ration of more that 100;*
- *promising results are emerging in other areas of natural resources management research. However, impacts in terms of the ultimate beneficiaries of such research cannot as yet be quantified;*
- *there is substantial germplasm exchange between SSA and other regions;*
- *policy research has filled critical gaps in knowledge important for policy makers in moving towards poverty alleviation, food security, and environmental protection in African countries;*
- *the CGIAR has contributed to scientific capacity building and institution strengthening through training that has reached more than 20,000 scientists, networks and collaborative research programmes in Africa;*
- *despite successes, there is little progress in increasing per capita food production and overall food security in the region;*
- *complementarity of efforts, multisectoral approaches, improved policies and access to inputs, markets and infrastructure are crucial to obtaining lasting and widespread impact;*
- *observations reinforce the need for a regional approach to research planning and implementation in the CGIAR, and for a much wider range of partnerships, including with development groups as well as other research groups.*

The paper provides clear evidence that the CGIAR and its partners have made substantial contributions to agricultural development in Africa. Much work remains to be done before a clear, quantitative and more comprehensive picture of impact on the CGIAR goals emerges. SPIA plans to pursue further the question of regional impacts of the CGIAR.

SPIA owes a large vote of thanks to Dr. Guido Gryseels, Deputy Executive Secretary of TAC and to Mr. Jan Groenewold of the TAC Secretariat, for their efforts in bringing together the materials reported on here and for preparing successive drafts of this paper. The CGIAR Centres are also to be thanked for their interaction and contributions in the preparation of this paper.

Hans Gregersen
Chair
Standing Panel on Impact Assessment

TABLE OF CONTENTS

Contributions made by the CGIAR and its Partners to Agricultural Development in Sub-Saharan Africa[1]

1. Agricultural Production and Consumption Trends in Sub-Saharan Africa

Sub-Saharan Africa (SSA), as defined by FAO in its 'Agriculture: Towards 2015/30' Study (FAO, 2000), consists of 47 countries of which only the Republic of South Africa (RSA) is classified as an industrial country. The other 46 are considered as developing countries, and contain 19 of the 25 poorest countries of the world. Nearly 75% of the population of SSA live in countries with an annual GDP/capita of less than US$ 400. The human poverty index for SSA indicates that more than 40% of its inhabitants are deprived of critical minimum levels of life expectancy, literacy and economic provisioning (TAC, 2000). FAO has estimated that 34% of the population of SSA, or 186 million people, is undernourished (FAO, 2000A).

The population of SSA is currently estimated to amount to 626 million of which 384 million or 61% depend on agriculture for their livelihood. The total land area of SSA is 2,455 million ha., of which 173 million ha. is under cultivation or permanent crops, about one quarter of the potentially arable area (FAO, 2001).

Agricultural production grew on average with 2.7% p.a. over the last two decades (1977-97), and with over 3% p.a. when only the last decade is considered (FAO, 2000B). Growth has slowed down to 2.2% p.a. during 1996-97 (see also Figures 1 and 2). Population growth has generally outstripped the growth in agricultural production. Population has been growing at between 2.4 and 2.9% during the last three decades. SSA stands outs as the only region where almost no progress has been made in raising average per caput food consumption or in incidence of undernourishment. This is illustrated in Table 1.1 and Figures 3 and 4.

In addition to Nigeria, a number of countries such as Benin, Burkina Faso, Ghana, Mauritius and Mauritania have also made significant progress but their weight in the regional average is too small. Except for Ghana and Nigeria, all of the countries with a population of over 15 million have lower per caput food consumption now than at any time in the last three decades, e.g., Congo D.R., Ethiopia, Kenya, Mozambique and Rwanda (FAO, 2000B).

As indicated earlier, on aggregate agricultural production in SSA has increased considerably over the last 4 decades. Between 1961 and 1997 expansion of crop production can, on average, be attributed to arable land expansion for 41%, to increases in cropping intensity for 24% and to yield increases for 35%. Over the last decade, the share of yield increases in

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[1] Paper prepared by Guido Gryseels and Jan Groenewold of the Secretariat of the Technical Advisory Committee of the CGIAR with inputs from Secretariat colleagues, Shellemiah Keya, Amir Kassam, Tim Kelley, Sirkka Immonen and Robert Bordonaro. Draft versions were discussed at TAC 80 and SPIA 22. The paper also benefited considerably from inputs from the Centres and their comments on an earlier draft. Agriculture is defined in the paper as including crops, livestock, forestry and fisheries. Sub-Saharan Africa is defined as including South Africa. Some statistics and studies, however, do not include South Africa and, where possible, this has been indicated in the text.

overall expansion has increased considerably. FAO (2000B) expects that yield increases will account for 62% of expected growth in crop production between 1995/97 and 2030.

Table 1.1: Per Caput Food Consumption (Kcal/person/day) and Incidence of Undernourishment in Sub-Saharan Africa

	Per Caput Food Consumption			% Population Undernourished		
	64/66	**84/86**	**95/97**	**69/71**	**79/81**	**95/97**
Developing Countries	2,053	2,433	2,626	37	29	18
Sub-Saharan Africa (SSA)	2,091	2,039	2,188	34	36	33
SSA (Excl. Nigeria)	2,036	2,054	2,058	36	35	39

Source: FAO, 2000B

Sub-Saharan Africa's population will continue to grow rapidly and in 2030 is even expected to still increase by 2% p.a. By that time, every third person added to the world population will be born in the region. However, the current spread of HIV/AIDS is likely to affect these growth estimates. The number of undernourished in SSA is expected to remain constant until 2015, and the World Food Summit (WFS) goal of reducing that number by half by that time will not be achieved (FAO, 2000A).

As most of Africa's poor and malnourished live in rural areas, agricultural and rural development, and research efforts underpinning it, are crucial for success of any strategy to reduce poverty and food insecurity.

2. CGIAR Activities in Perspective

The CGIAR was established in 1971 and of the four centres it supported at its inception only one, IITA, was based in SSA. Currently four of the centres, ICRAF, ILRI, WARDA and IITA have their headquarters in the region. The other 12 also have activities in SSA and in total there are about 56 offices of CGIAR Centres throughout the region. CGIAR research in the region focuses on genetic improvement of food crops, ruminant livestock, trees and fish important to the poor, on integrated natural resources management including biodiversity research, policy research, and capacity building.

During the 30 years of its existence, it is estimated that about 42% of the CGIAR resources have been allocated to research and capacity strengthening for the region. This does not mean that of the US$ 4.8 billion invested in the CGIAR since its inception that US$ 2.0 billion was directly expended in SSA, but that this amount of resources was allocated to solve problems specific to the needs of the region.

In this paper, we provide an overview of the major contributions of the CGIAR and its partners to agricultural development in SSA. We only report on achievements specific to

SSA and not on payoff from global efforts from which the region also reaps benefits, such as through contributions to science. To organize the discussion, we have disaggregated the contributions of the CGIAR by its logframe outputs as defined in the most recent vision and strategy of the System (TAC 2000). This paper reports on available information on intermediate impacts such as yield, output, sustainability, capacity and income increases, rather than ultimate impact in terms of the CGIAR goals of poverty reduction, and sustainable food security. Studies documenting this ultimate impact are in progress. It should also be noted that until 1992 the CGIAR goal was defined in terms of increasing productivity and that progress towards the current goal of reducing poverty is not easy to measure retroactively. Finally, it should be taken into account that the methodology of quantifying achievements is much more advanced for crop genetics work than in other fields such as integrated natural resources management, policy research or capacity building. The human and partnership dimensions of collaborative research cannot be described in quantitative terms.

The specific contributions of the CGIAR cannot easily be separated from those of its partners, especially groups within the African NARS. The CGIAR accounts for 10% of total expenditure on agricultural research in the region. About 90% of agricultural research in SSA is funded by countries of the region (ISNAR, 2000). Nearly all of the CGIAR research is conducted through partnership arrangements and it would be impossible to separate the contributions of one partner from that of another. It is through the partnerships that have been created between CGIAR scientists and NARS scientists and extensionists that the contributions of the CGIAR mainly have been made. Most centres reach their target groups through NARS intermediaries. Thus, whenever reference is made in this paper to the contributions of the CGIAR, it should be read as those of a partnership.

Our overall message in this paper is one of hope. The impact of agricultural research efforts is substantial in many countries. The payoff from varietal improvement efforts in the region appears to be high especially during the last decade. "Technological momentum is high for the region" Evenson and Gollin (2001) note. However, this impact is masked in "average" figures. SSA is unusually heterogeneous: politically, culturally, economically and ecologically. Progress in some countries is masked by declines in other countries often due to war and drought. Furthermore, the substantial growth in overall agricultural and food production has fallen short of what is needed to feed the rapidly expanding population. As a result, there is little progress in increasing per caput food production or consumption. Furthermore, while farmers make much greater use of modern varieties, often they do not have adequate access to the inputs needed to achieve higher yield potentials. Major efforts are also required in improving institutes, infrastructure, markets and policies to support and sustain agricultural growth. For agricultural research to have much greater and lasting impact on agricultural and economic development, a more holistic and multisector effort will be required that draws on much wider partnerships with other research and development agencies. These observations reinforce the need for a regional approach to research planning and implementation for the CGIAR and its partners. More detailed elaboration of the rationale and advantages of the regional approach to research is given in TAC (2001).

3. Germplasm Improvement[2]

3.1 Overview

The best-documented contribution of the CGIAR to agricultural development in SSA has been through its work on crop genetic improvement and the production of modern varieties. In 1970, modern varieties were used on only about 1% of the crop area of SSA. The only exception was wheat for which about 5% of the area was planted to modern varieties. The spread of modern varieties in farmers' fields grew very rapidly during the eighties and even more in the nineties. Today approximately 26% of the area planted to food crops is covered with improved cultivars (Table 1). Area planted with modern varieties of wheat increased from 5% in 1970 to 52% in 1998, of rice from 0 to 40%, of potatoes from 0 to 78%, and of sorghum from 0 to 26%.

While the crop genetic improvement component is not the only one contributing to productivity growth, it is the major component in most developing countries. In SSA, the contribution of crop genetic improvement to yield growth amounted to 0.017 during the sixties, 0.142 during the seventies, 0.358 during the eighties and 0.497 during the nineties. Clearly there is a rapidly increasing share in the contribution of genetic improvement to yield growth over time. In SSA, the contribution of genetic improvement to yield growth is below that of other regions due to the historic opportunities for increasing production through expansion of area (Table 2). According to Evenson and Gollin, the effects of varietal improvement efforts on yields have become particularly visible during the last decade. They argue that differential research investments and research time lags are the primary reason for the lower performance of Africa in comparison to other regions. An overview of average yields, production and area harvested of most of the major food crops in SSA is provided in Table 3. These "averages" mask to some extent the considerable successes that have been obtained in many countries.

The CGIAR content in modern varieties was high in all crops under study. For SSA, on average more than half of modern varieties were based on a CGIAR cross, and an additional 25% had a CGIAR-crossed ancestor. Much of the impact of modern varieties on yields in SSA occurred during the last decade. This delay, compared to other regions, is due to differential research investments and time lags. Evenson and Gollin (2001) also note that varietal improvement efforts in Africa initially focused on the use of varieties from other regions and that not until the 1980s was the value of local varieties recognized.

Evenson and Gollin (2001) have estimated in a simulation study that in the absence of the CGIAR, the spread of modern varieties as well as of production of crops concerned would have been 50-75% lower depending on the crops. These simulations also show that in the absence of the CGIAR's crop genetic improvement work, the incidence of child malnutrition in SSA would be a lot higher and calorie availability substantially lower.

[2] This section draws heavily on the results of the study on the impact of CGIAR germplasm improvement research commissioned by SPIA and conducted in collaboration with the crop centres of the CGIAR. It was led by Prof. Robert Evenson of Yale University. The study will be published by CABI by the end of 2001 under the title "Crop Variety Improvement and Its Effect on Productivity: The Impact of International Agricultural Development" by R.E. Evenson and D. Gollin (Eds). A synthesis of the results has been submitted to MTM, "The Green Revolution at the End of the Twentieth Century" (Doc. No. SDR/TAC:IAR/01/12).

An overview of the contributions of CGIAR germplasm improvement research to agricultural development by crop is provided in the following sections. The contributions of the CGIAR through emergency programmes such as the Seeds of Hope programme or famine relief in Eastern and Southern Africa have not been included in this assessment.

3.2 Maize

Maize is the single most important food crop in SSA, contributing more than 40% of total cereal production. The crop is especially important in Eastern and Southern Africa where it accounts for the majority of calories provided by starchy staples. Two CGIAR Centres, CIMMYT and IITA, allocate substantial resources to maize research which is undertaken in close collaboration with national research systems. Investment in maize research by NARS has increased rapidly over the last four decades. The involvement of the private sector in maize breeding is larger than in any other crop, accounting for more than a quarter of research activities.

Maize improvement research has been particularly successful and has resulted in a steady stream of improved varieties, both open pollinated (OPV) and hybrids. The proportion of hybrids as a percentage of total releases has remained relatively stable at 40% over the past three decades (Maredia *et al*, 1998). Overall, maize improvement has been a success story both in Eastern and Southern Africa and, more recently, also in Western and Central Africa. About half of the maize area in Eastern and Southern Africa is planted with modern varieties/improved germplasm (Morris *et al*, 2001). This is comparable with other developing country regions.

More than a third of the improved maize varieties in Eastern and Southern Africa have been developed using CIMMYT germplasm. Of all maize varieties released by the public sector since 1966, 37% were developed using CIMMYT source materials. Use of CIMMYT germplasm increased steadily over time; of the varieties released since 1990, over 55% were developed using CIMMYT source materials. In 1996, approximately 1.6 million ha in eastern and southern Africa were planted to varieties that had been developed using CIMMYT germplasm. This area excludes South Africa, where farmers grow mainly temperate materials not targeted by CIMMYT's breeding programme. The varieties developed by CIMMYT and its partners have higher yields, improved resistance to diseases (maize streak virus and grey leaf spot) and offer farmers earlier maturity options, making them more robust for small holder food security and more flexible for incorporation into cropping system niches.

In Western and Central African countries, half of the improved germplasm came from IITA and one sixth from CIMMYT (Douthwaite and Manyong, 2000). Improved maize varieties were planted on 37% of maize area, and their yields were an average 45% above traditional varieties. The additional production as a result of these increased yields provides staple food for 9 million people (Manyong *et al*, 2001). In Western and Central Africa, almost all of the improved germplasm is OPVs, in contrast to the widespread adoption of hybrids in Eastern and Southern Africa. These differences can be attributed to ecological variations, to targeting of the research and to the greater prevalence of large-scale commercial farming in Eastern and Southern Africa. The adoption of improved maize germplasm has had a significant effect on maize production in Africa. Yield gains at the farm level for hybrids have been between 30 and 40% and for OPVs around 15% (Maredia *et al*, 1998). In addition to the yield gains, yield stability has been enhanced by the release of disease resistant varieties, especially the maize streak virus. Several studies have assessed country-specific impact of maize research and have calculated rate of returns to investment in maize research (Anandajayasekeram and Martella, 1999; Omiti *et al*, 2000). These studies invariably show a high rate of return to investment in maize research.

Quality protein maize (QPM), which has been introduced into more than nine countries in SSA through the efforts of CIMMYT, national programmes, and Sasakawa-Global 2000, can increase protein availability in areas where maize consumption is high and better sources of protein are unobtainable—often because people cannot afford them. Because it contains nearly twice the lysine and tryptophan—amino acids essential for human nutrition—as normal maize, QPM delivers better quality protein to consumers than they would obtain simply by consuming normal maize. CIMMYT and its partners have developed stable, high yielding, and disease- and storage-pest resistant QPM hybrids and varieties for diverse settings. In tests in over 40 nations worldwide, QPM hybrids and open pollinated varieties often had a yield advantage of one ton or more per hectare over the best normal maize hybrids. The current area under QPM maize in SSA is estimated to be around 300,000 hectares and is projected to double in the next three years.

3.3 Sorghum

Sorghum is the second most important cereal crop in SSA. It is a major crop of the lowland semi-arid tropics where it is especially important, together with millet, as a staple food for tens of millions of very poor people in drought-prone areas. It is particularly important in the sub-humid areas of Africa and the mid-altitude areas of Eastern and Southern Africa. Sorghum and millet together account for more than half of West Africa's cereal production. For a long time, there has been a widely shared impression that there was very little impact from sorghum research given the technical difficulties involved in breeding of crops for areas with very low or sporadic rainfall and low soil fertility. However, over the last five years evidence has accumulated of widespread impact of ICRISAT's sorghum research in Nigeria, The Cameroon, Senegal and Chad. The availability of inorganic fertilizer and quality seeds are a major constraint in the adoption of improved varieties. As a result, there is a widespread variation by country of the rate of adoption, which ranges, for example, from 3% in Sudan to 36% in Zimbabwe during 1997. In The Cameroon improved sorghum varieties account for 33% of the total sorghum area and for 27% in Chad. An ICRISAT study indicated that in Mali, the net present value (NPV) from the improved sorghum variety amounted to US$ 16 million with an internal rate of return (IRR) of 69%, in Chad the NPV amounted to US$ 15 million with an IRR of 95%, and in The Cameroon the NPV amounted to US$ 5 million with an IRR of 75% (Deb and Bantilan, 2001).

3.4 Pearl Millet

Pearl Millet is the third most important cereal crop and grows in the semi-arid tropics. It produces grain and fodder under conditions that are too hot or too dry and on soils too poor for sorghum and maize. Pearl millet is the staple cereal throughout semi-arid West Africa where it accounts for half the daily calorie intake and one third of the protein. As in the case of sorghum, much of the adoption of improved varieties has resulted from dissemination of improved seeds through drought relief programmes. The adoption rates have varied between 20 and 30% in Zambia, Mali, Zimbabwe and Botswana and have been highest in Namibia where it amounted to nearly 50%. Yields of improved varieties under farmer conditions have been about 40%, higher than those of the best local varieties. The NPV from improved millet varieties in Mali amounted to US$ 25 million with an IRR of 50%. The IRR in Zimbabwe amounted to 44% and to 50% in Namibia (Deb and Bantilan, 2001).

3.5 Rice

Rice is a relatively new crop in many areas of SSA. Fuelled by increasing urbanization policy and cheap imports, demand for rice has been expanding rapidly resulting in high levels of rice imports especially in West Africa but also higher domestic production. Rice is now grown in nearly every country of SSA. WARDA, IRRI and IITA over time have had a major involvement in rice research. About 40% of the total rice area in SSA is planted with improved varieties. In the irrigated areas, nearly all of the rice planted is modern varieties. In the mangrove rice systems of Sierra Leone, Mali and The Gambia, nearly all of the rice grown is from improved varieties also. Most of the adoption of the improved varieties has occurred over the last 10-15 years.

Of the 197 improved varieties that have been released, 54 were produced by CGIAR Centres while an additional 31 had parents or ancestors developed by the CGIAR. According to a WARDA study, the cumulative impact of genetic enhancement and technology transfer contributed about US$ 374 million to the regional rice income in 1998. CGIAR institutes directly developed over 25% of all improved varieties currently in use and these contributed about 29% of the estimated financial gains. The share of CGIAR released varieties increases to about 40% and the contribution to financial gain to 46% when crosses of CGIAR and NARS materials are taken into account. WARDA has also played an important role in the spread of traditional but highly productive varieties with increased yields in some of the most difficult ecologies in the region.

Overall, case studies conducted by WARDA in several countries over the past eight years indicate that the return to investment in varietal improvement has always exceeded 20% annually and in certain cases amounted to more than 100% a year (Dalton and Guei, 2001).

The new African (NERICA) rice cultivars, recently developed by WARDA, show promise for a significant impact on rice production in West Africa. Based on crosses between African rice (Oryza glaberrima) and Asian rice (Oryza sativa), NERICAs have high yield potential, short growth cycle, and are weed competitive and resistant to major African pests and diseases. They are already having an impact in Guinea where about 8,000 hectares were grown in 2000, generating a minimum gain of US$ 2.5 million over pre-NERICA production.

Since 1975, 39 countries in SSA have had access to elite rice germplasm from Asia and Latin America, as well as Africa itself, through the International Network for Genetic Evaluation of Rice (INGER) (Chaudhary *et al*, 1998). At first, INGER-Africa was coordinated by IRRI in partnership with IITA; since 1997, however, IRRI has supported WARDA in that role.

Between 1975 and 1997, a total of 136 INGER lines were released as 225 varieties in 27 countries. The released varieties originated from 22 national programmes (73) and from IRRI (38), IITA (24), and CIAT (1). The adoption of INGER lines has been most marked in West Africa (in particular in Benin, Cameroon, and Ghana), but was also significant in Mozambique and Tanzania. In recent years, between 1995 and 2000, about 3,400 varieties or breeding lines were sent to 15 countries, and these were channelled into their respective national variety testing programmes or used as parental materials in rice breeding.

3.6 Wheat

Wheat is the fifth most important cereal crop in SSA but accounts for more than half of cereal imports in the region. It is grown mostly in Eastern and Southern Africa. As in the case of rice, the consumption of wheat has increased dramatically due to increasing urbanization and policy distortions. Nearly all of the wheats grown in Africa (excluding South Africa) are spring wheat varieties and the number of varieties released per million ha of wheat area is estimated to be about five a year which is more than twice the rate of other developing regions. Almost 85% of the varieties released between 1966 and 1990 were direct transfers from CIMMYT. Between 1966 and 1997, 212 CIMMYT-related wheat varieties were released in SSA. About 2.1 million hectares were sown to CIMMYT-related wheat in 1997. About 50% of the cultivated wheat area is planted with modern varieties. This is lower than in other developing areas due to the difficult agroecological conditions and low use of inputs in SSA but represents the highest rate of adoption of modern varieties among cereal crops. Between 1977 and 1990, the adoption of improved wheat varieties has contributed to about 150,000 tons of additional wheat production annually in Africa, generating an annual economic surplus of about US$30 million (Byerlee and Moya, 1993). More recently, the IRR for wheat improvement research in Africa has been estimated to be 23%. (See also Heisey *et al*, 2001.)

3.7 Barley

In Ethiopia, approximately one million ha is planted annually with barley, mostly by poor smallholder farmers. It is a key food crop in dry (drought-prone) highland areas. The rate of return to Ethiopia's barley research was estimated by ICARDA at 44%. ICARDA's contribution to the Ethiopian germplasm release was 20% but the Centre's contribution perhaps was greatest in research methodology as the NARS shifted the barley breeding programme from being experiment-station based to agroecology based and emphasized the utilization of local land races. This was a major change but essential for Ethiopia because of its variable agroecologies (Hassan and Shiheed, 2001; Erskine, personal communication).

3.8 Cassava

Africa is the largest producer of cassava, accounting for half of total world production. It is an important food crop in the humid and sub-humid tropics of SSA and nearly all cassava production is for human consumption. It is grown mostly by poor small-scale farmers in more marginal areas as the crop tolerates low fertility soils and droughts. In SSA it accounts for about 60% of the harvested root crop area and is a major source of energy for over 200 million people in Central and Western Africa. It is a crop with a long production cycle (9-12 months) so inputs have to be used over a long period also to protect against a variety of pests and diseases. Breeding efforts have focused on substituting biological adaptation for purchased inputs especially pesticides and fungicides. The breeding strategy has focused more on resistance than on yield potential. Improved germplasm from Asia and Latin America has found its way into SSA. Yields have grown faster in Africa than elsewhere, but remain the lowest in the world. IITA and CIAT have provided the majority of the 130 varieties released in SSA. During the nineties, about 82% of the cassava area planted with improved varieties was planted with materials from IITA or CIAT (Manyong, 2000). It has been estimated that 18% of the total cassava area in SSA has been planted with CGIAR varieties ranging from 1% in Zambia to over 30% in Tanzania, Uganda and Swaziland. The total value of incremental production due to improved cassava cultivars has been estimated at

US$ 327 million. The benefits were the highest in the Democratic Republic of Congo and in Nigeria (Manyong *et al*, 2001).

3.9 Potato/Sweet Potato

Potato is an important crop in the highlands of Eastern and Central Africa covering about 110,000 ha. Nearly 50% of the potato growing area is now planted with improved disease-resistant varieties, which on average yield 40% more than traditional varieties.

Potatoes are expanding in area in SSA, and yield is also increasing with intensification. CIP-related materials account for about 60% of released varieties and about 40% of growing area in East and Central Africa. CIP and its partners impact has been greatest in some of the smaller countries of the region. Additionally, CIP varieties selected by the national programme are cultivated on about one-third of potato-growing area in Cameroon, the largest potato-producing country in West Africa. In the highlands of Central Africa, these late blight-resistant varieties are still favoured by women farmers engaged in semi-subsistence production. The short dormancy of these varieties also allows them to fit easily into a bimodal cropping calendar leading to enhanced food security. These varieties have also made an important contribution to disaster relief as refugees fled with these improved clones to highland campsites where neighbouring farmers substantially expanded their production of these varieties in response to greatly increased demand.

Results from on-farm trials suggest that these varieties increased yield by about 40% equivalent or about 3 t/ha. Moreover, improved seed programmes also contributed strongly to enhanced potato productivity in the Central African Highlands in the 1980s and early 1990s, but these have been casualties of civil war.

The rate of return to potato research in Eastern and Central Africa has been estimated by CIP at 84%, generating an annual benefit stream of US$ 10 million to the region. However, due to civil war and political unrest during the nineties, the annual rate of varietal release, which peaked at about 3.7 per year during the eighties, has now slowed down considerably. Nearly 60% of released varieties are based on CIP materials. Nearly 40% of the potato growing area of SSA is planted to CIP-related materials (Walker *et al*, 2001).

The impact of CIP's research on sweet potato crop improvement in SSA has thus far been more modest than its impact on household potato production and consumption. CIP received the mandate for sweet potato crop improvement for SSA from IITA in 1987. CIP has supported the release, mainly from the best of local land race materials, of about 15 sweet potato varieties in East and Southern Africa. CIP's emphases in strengthening sweet potato research in national programmes is focused on the generation and farmer acceptance of orange-fleshed types to mitigate the severe nutritional problem of Vitamin A deficiency, the deployment of virus resistance so that global germplasm can play a role in genetic improvement, and on the integrated management of sweet potato weevil, the most important pest in the region. The work on orange-fleshed sweet potato is cast in a food-based approach to the problem of Vitamin A deficiency. CIP's scientists and their partners are currently carrying out an ex-ante impact assessment of the potential future contribution of these varieties in the region.

3.10 Pulses and Legumes

Phaseolus Beans

In Africa, bean improvement work began much later than in LAC and the diffusions curves are estimated to be in very early stages in many countries. Nonetheless, a CIAT study in several African bean-producing countries found that on average, 15% of bean area was planted to CIAT-related beans in 1998. Yield gains associated with these new varieties were 400 kg per hectare. In 1998, the gross value of increased production associated with CIAT-related varieties in the study countries was US$ 26 million, with a cumulative impact of US$ 116 million.[3]

Yield gains associated with CIAT-related varieties are high compared to FAO statistics on regional yield changes. This may be due to the fact that adoption of CIAT-related varieties involves a shift from bush beans to climbing beans. Climbing beans can yield one to two tons per hectare more than bush beans; however, they are much more input-intensive, a fact which must be considered in assessing their overall productivity and economic impacts.

Climbing beans were introduced into the Great Lakes region in the early 1980s, and by 1998 Rwanda and the eastern areas of the DR Congo were estimated to have 16 and 48%, respectively, of their bean area planted to these varieties. Similar figures are likely for Burundi, but no data are available from that country. It is estimated that by 1994 in Rwanda alone, climbing beans were generating net benefits of US$ 8-15 million annually (Sperling *et al*, 1994).

CIAT has estimated that as of 1998 the IRR for research on bean in Africa was 60%. The breeding programme in Africa has been able to benefit from past work in LAC and reduce the lag time between the establishment of a program and the release of a variety. Net benefits to research in Africa became positive after just four years, compared with 14 years in LAC.

The impact of improved bean varieties in SSA was further assessed by CIAT using a case study approach in Uganda (David *et al*, 2000). Two modern bush bean varieties had been introduced in the mid-1990s, about 25 years after the first successful introduction by the Ugandan NARS of new bean germplasm based on CIAT-bred lines. Estimates are that more than 1,000 tons of seed were distributed by 1999, with adoption rates in sampled farmer households close to 74% in 1998. The area cropped to the two improved bush bean varieties was estimated at about 49,000 ha, with a yield increase over local cultivars ranging from 40% to 70%. Though adopters of improved bean varieties did not show significant income gains in the first cropping season, the per capita consumption of beans increased significantly over the historical figures. Some if not most of the increased consumption can be attributed to the higher productivity of the new variety. The impact on wealth and gender was found to be neutral. The greatest benefits went to households of average wealth with sufficient resources (land and labour) to take advantage of the yield increases. The study found that modern bean varieties can contribute to poverty alleviation, although the gains in quantitative measures of welfare as income and per capita food consumption may be modest (Johnson *et al*, 2001).

[3] Values in 1990 US dollars.

Pigeon Pea

Pigeon pea is a crop of growing importance in East Africa, which now contributes 12% of global production. It is grown by subsistence farmers often on poor soils and with few inputs. ICRISAT and its partners have released three improved pigeon pea varieties in recent years, which are now being adopted in Kenya, Malawi, Uganda and Sudan. Initial results suggest that the new varieties allow for yields that are 55% higher.

Chickpea

Chickpea is an important crop especially in Ethiopia where it is part of the cereal/pulse rotation system of many smallholder highland farmers. ICRISAT, in collaboration with the Ethiopian NARO, has released four improved chickpea varieties, which are being widely adopted. The area under chickpea cultivation in Ethiopia has doubled in recent years.

Groundnut

Groundnut is an important crop in Western and Southern Africa. The region accounts for nearly 20% of world production but yields are well below those obtained elsewhere. ICRISAT has developed varieties that are resistant to the rosette virus. Approximately one third of the groundnut area in Malawi is planted with this improved variety.

Lentil

Lentil is an important food legume for smallholders in parts of Central and NW Ethiopia growing on about 50,000 ha annually. Three cultivars originated from ICARDA ('Adaa', 'Gudo' and 'Chalew') were the only unaffected varieties in research centres and farmers fields after a rust epidemic wiped out most of the local land races in Ethiopia in the winter of 1997 (Bejiga, et al 1998). One of these varieties 'Adaa' is now spreading rapidly in the country and the Ministry of Agriculture set up a programme of purchasing the seed and distributing it to farmers. The yield of 'Adaa' is estimated at 1.5 t/ha compared to 0.7 t/ha with local lines. Lentils are an important cash crop for small farmers around the Addis Ababa population centre (Shiheed and Hassan, 2001).

Cowpea

Cowpea is the most important food legume in SSA, contributing to more than 50% of total legume production. The crop was domesticated in the Sahel and has its centre of diversity in West Africa. It is now grown by tens of millions small holder farmers throughout Africa where two hundred million children, women and men consume cowpea often, even daily when it is available (University of Purdue, 2001). Cowpea is rich in protein and digestible carbohydrate and combined with cereals gives a balanced amino acid intake (Inaizumi et al., 1999). It is widely known as the crop of the poor because its green pods and leaves are earliest foods available at the end of the “hungry time”.

In 2000 cowpea was planted on 9.6 million hectares (FAOSTAT, 2000) in SSA and 9.8 million hectares worldwide. More than five million hectares, or 53% of the SSA total, were planted in Nigeria. This makes the country the largest producer of cowpea in the world, thanks in part to the efforts of IITA and NARS partners’ cowpea breeding programmes. In the thirty years from 1971 to 2000 Nigerian cowpea production increased 6.3 times helped by a doubling of yields. In dollar terms, this increased annual production of 1.3 million tonnes saved the Government of Nigeria US$ 650 million in cowpea imports in 2000 alone (Ortiz, 1998).

Nigeria's increased cowpea production has more than kept up with its burgeoning population, allowing per capita consumption of cowpea to increase from 16kg per year in 1971 to 45kg per year in 2000

Improved cowpea cultivars have underpinned Nigeria's cowpea revolution. IITA holds the world's ex-situ cowpea collection of 15,200 landraces from 100 countries and 1,600 wild accessions from Africa. Its role in the development and dissemination of new cowpea cultivars has been catalytic rather than independent of Nigerian and African NARS. IITA has worked particularly closely with the Institute of Agricultural Research (IAR) in Zaria, Northern Nigeria, the University of Ife (Nigeria) and Senegal. Since the early 1990s IITA has co-ordinated a Swiss-funded project "Protection Ecologiquement Durable du Niébé," or PEDUNE (recently renamed to PRONAF) that aims to increase cowpea production in the Sahel and African savannas by applying ecologically sustainable pest control. Project activities are focused in Benin, Burkina Faso, Mozambique, Niger, Nigeria, Cameroon, Ghana, Mali, and Senegal and have contributed to the development and distribution of improved cowpea cultivars.

The successful cultivars that have emerged from these partnerships have been suitable for intercropping and have combined stable yields with multiple pest and disease resistance (including parasitic weeds), photoinsensitivity, different maturity periods including extra early varieties, erect or determinate growth, and drought tolerance (Ortiz, 1998). Since 1992 IITA and ILRI have been working together to develop dual-purpose cowpeas that provide both grain and animal fodder, thus fostering crop-livestock integration, necessary for nutrient recycling and sustainable agriculture in the region (Okike et al. 2000). Improved cultivars have spread to over 50 countries in Africa, Asia, America and the Pacific (Ortiz, 1998). Studies on the return to investment of cowpea research and extension in several African countries have shown high returns of between 16% and 92%. (Sanders et al., 1994; Schwarz et al., 1993; Mazzucato and Ly, 1992; Sterns and Bernstein, 1994 and University of Purdue, 2001). In Mali, for example, Sanders et al. (1994) estimate that the monetary benefits of cowpea research are about $4.8 million.

Soybean

Soybean is rapidly becoming a major food and cash crop in Nigeria. This is the result of the adoption of newly developed varieties that can produce high yields, can be kept well in storage, do not require expensive additional production inputs, and which can be grown profitably by small holder farmers. The progress made is largely due to the fact that research focused simultaneously on the development of new varieties and of appropriate utilization technologies.

Soybean is a high-quality protein food that provides greater income opportunities for male and female farmers, and allows for soil fertility improvement. Recently IITA studied the benefits gained from the introduction of improved soybean varieties and utilization technologies in Benue State. Originally, men provided twice as much labour as women in soybean production. However, more and more women switched to soybean production, as the crop became more profitable and improved varieties were more readily available. Improved varieties were widely adopted by farmers. The rates of adoption increased from

9% in 1989 to 75% in 1997. Soybean production had a positive impact on farmer' incomes accounting for about half of the total farm income for men as well as for women. Soybean became integrated in the daily diet of the majority of farmers and is rapidly becoming a food staple among the local population. The nutritional status of children had improved in soybean producing and using households.

Recent production statistics on soybean confirm the success of this new technology. Between 1991 and 1998 the area harvested in Nigeria has increased by 16% reaching 543,000 ha. Over the same period, the total production has increased from 145,000 to 361,000 tonnes or by a total of 149%. The increases are mostly the result of significantly higher yields per hectare, following the introduction of improved varieties and production techniques.

Dual-purpose grain legume varieties produce a higher amount of biomass in addition to good grain yields, and fix higher amounts of nitrogen. Soybean varieties are now available that have these characteristics, and these improved materials are being increasingly used by farmers in the current maize-based cropping systems. These varieties produce about 2.5 tonnes of grains and 3 tonnes of forage, and there is every indication that further progress can be made. Comparison of the nitrogen fixed by these improved materials with traditionally grown varieties shows a positive nitrogen balance in a maize rotation, and leads to significant increases in maize yield.

Maize in the Guinea savanna suffers very serious losses from the parasitic weed *Striga hermonthica.* This is the most severe biotic constraint to maize production in this zone. Maize varieties with partial resistance to this parasitic weed 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 developed by IITA 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 reduces the pressure on the following maize crop. Very significant variation among soybean cultivars has been found with respect to the induction of striga seed germination capacity. Therefore in the breeding programme 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 phosphor, and striga control through the use of appropriate soybean and maize varieties, as well as the introduction of nitrogen 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 of land-use productivity and with further spread, there will certainly be additional economic and environmental benefits. The development of new improved materials, as well as effective livestock integration, will further contribute to the success of these cropping systems and to the improvement of the economic well being of the farmers.

Faba Bean

Faba bean is an important crop in the cereal/pulse rotation system of farmers in the Ethiopian highlands. Applying the recommended cultivars of faba bean, NC 58 and Kassa, for mid-altitudes and, CS 20 DK, KUSE2-27-33 and 20 DK-sel., for high altitudes with the recommended agronomic practices (seeding rate, planting period, weed control) resulted in yield increases with a range of 33-154%. Economic evaluation under the farmers' conditions (demonstration fields) gave an average marginal rate of return (MRR) of 1303% indicating a very high profit margin. Adoption rates were: 61% of the farmers adopted improved cultivars, 32% adopted P fertilization and 60% adopted weed control (hand weeding).

In Sudan, six varieties of faba bean developed by ICARDA were released to the farmers and gave 8-20% more yield than local cultivars. Use of the new recommended varieties together with recommended agronomic practices (planting date, frequency irrigation, weed and pest control) resulted in a net benefit of 219 LS/ha.

3.11 Banana and Plantain

Banana and plantain are two of the most important food crops in humid and sub-humid areas throughout SSA, providing a staple for tens of millions of people. The domestic consumption rate reaches its highest in the East African Highlands, where over half the daily calorie intake is obtained from bananas. The producers are predominantly small-scale farmers.

The importance of the crop to food security has been neglected until relatively recently. Levels of production have increased more than two-fold since the 1960s through the doubling of the area under harvest. Yields from smallholdings, however, have largely decreased and no improved varieties have been introduced on a large scale.

In 1987, African governments encouraged IITA to initiate a banana breeding programme to help combat black sigatoka disease. This fungal leaf spot disease causes significant yield loss in plantains, an important food and cash crop to more than 70 million people in SSA. An interim measure adopted by IITA in the late 1980s, was the introduction from Asia of black sigatoka-resistant cooking bananas (Ferris et al. 1998), while the long-term strategy was to develop black sigatoka resistant plantains. After their introduction to Nigeria, cooking banana plantlets were produced in two tissue culture laboratories located at IITA-Onne and the Imo Agricultural Development Programme-Owerri. With the collaboration of 24 institutions[4], vegetatively propagated planting materials (suckers) were distributed to 29585 farmers in 710 villages.

IITA has examined the adoption and diffusion of cooking banana in Nigeria (IITA, 2000). Cooking bananas have gained a high level of acceptance and spread among the people, and thus established itself within the farming system of the villages under study. The crop has been adopted by 55% of farmers, occupying about 26% of total fields, while its cultivation has increased by more than 930% since introduction, with a multiplication rate of 600% across farmers. As cooking banana was neither a traditional crop nor an improved variety from an existing one, the level and rate of adoption and diffusion are quite encouraging. At

[4] State Ministries of Agriculture, Agricultural Development Programmes, Agricultural departments of Local Government Areas, and non-public organisations such as Shell Petroleum, Nigerian Agip Oil and the Anglican Diocese of Awka.

the end of the 1990s, about 80% of farmers, who adopted this new crop, were selling 10 to 90% of their total cooking banana production, while the other 20% produced entirely for household consumption. About 58% farmers sold at least 50% of their cooking banana. It appears that cooking banana can provide a suitable supplement (or even substitute) to plantain for some farmers and consumers in Nigeria.

In the 1990s, IITA successfully developed several plantain hybrids that are resistant to black sigatoka and out-yield the best plantains at the breeding station. One of the most promising is PITA 14 (or TMPx 7152-2) because or its early fruiting, high bunch weight and big fruits (Ortiz and Vuylsteke, 1998). While detailed analysis of the acceptability of PITA 14 in southeastern Nigeria is underway, it is noteworthy that several farmers have established sucker multiplication plots and are selling suckers to other farmers (IITA, 2000). An overview of genetic research strategies for plantain is provided by Vuylsteke (2001).

The International Network for the Improvement of Banana and Plantain (INIBAP) has been supporting breeding efforts and germplasm evaluation around the world since 1985. INIBAP is participating in the introduction of 24 improved cultivars to small holders in northeastern Tanzania. The first results are indicating that yield increases of up to 150%, from 8.8kg to 22.0kg/bunch, are attainable in the areas worst affected by pests and diseases and poor soil fertility.

The Kagera Community Development Project (KCDP) and Katholieke Universiteit Leuven (KUL) have partnered up in an initiative to deliver one million banana plants of high-performing varieties to farmers in Kagera, Tanzania. The INIBAP genebank is supplying the germplasm. By July 2001, over 70,000 *in vitro* plants will have been supplied to be planted out in fields over a wide area in Kagera. The farmers in the region have had no experience of these varieties or of *in vitro* plantlets. The plants are, therefore, grown and multiplied and provided to farmers in a form with which they are familiar (i.e. 1-1.5 m suckers). This also helps to provide a sustainable source of the new varieties. Current estimates indicate that the multiplication fields will be producing around 120,000 suckers in 2001. The new varieties appear to be adopted successfully into farmers' fields, especially where yields have been poor in the past. From initial data provided by farmers, the improved varieties are outperforming existing varieties, bunch weight having increased by over a third.

3.12 Neglected and Underutilized Crops

The CGIAR also gives attention to particular crops that are of specific importance to the poor, yet are neglected by research. These crops, including certain leafy vegetables, coconut, tuber crops, grain legumes, small grains, cucubits and forestry species are grown and consumed by poor and disadvantaged farmers, especially women.

The focus on leafy vegetables is particularly important for women and children, because they are the ones that suffer most from iron and vitamin A deficiency that these crops can help to alleviate. Leafy vegetables are an integral part of farming and consumption systems throughout Africa. They are particularly important as a buffer during periods of famine and natural disasters. Many plants grow in the wild or as weeds often in cultivated areas but they have also been domesticated through semi-cultivation or cultivation. When domesticated, they require few inputs and tend to grow and produce in areas where cultivation of exotic vegetables meets with difficulty.

In response to the decline in the distribution and use of African leafy vegetable genetic resources, IPGRI initiated a collaborative research project with scientists, development organizations and technologists from Botswana, Cameroon, Kenya, Senegal and Zimbabwe. A major focus of the research was to document the indigenous knowledge on the diversity and uses of leafy vegetable species, by working with communities to identify the species that were most important, based on uses and availability. Genetic diversity within individual species is important for their improvement both in quality and productivity through selection and breeding. Varieties that meet consumer taste requirements required less preparation, and were more productive (having a greater leaf area per plant and delayed flowering), were usually in high demand, and were among those included in the priority species that were identified. A new project is being started now to conduct additional research on more than 60 priority species identified.

Coconut farmers are usually resource-poor smallholders. In the last decade, coconut farmers have been suffering from low coconut productivity, low prices and unstable markets for their traditional copra and coconut oil products, which gave them an average annual income of only US$180-200 per year. To improve the situation, there is a need to provide coconut farmers with high-yielding and adapted varieties, some of which are potential multipurpose varieties and suitable for the production of high-value products. Within households of coconut growing communities, the crop is an important source of income, particularly for women, through offering the potential for high value products other than the traditional products of coconut meat, copra and oil.

Coconut work is carried out through the coconut network COGENT, which is coordinated by IPGRI. COGENT involves a broad range of stakeholders including organizations with direct contact with coconut growing communities, and representatives of those communities. Research in 14 participating laboratories has raised the efficiency of seedling establishment from embryos from 14-55% to 31-80 % using a range of varieties. The project has built capacity by training 23 NARS researchers from as many countries in the use of *in vitro* techniques at hands-on training workshops.

4. Integrated Natural Resources Management

4.1 Production Systems and Natural Resources Management Research

The CGIAR has been active across Africa in research related to management and improvement of natural resources such as water, soils, forests and genetic resources. All centres in the region devote a significant portion of their resources to such activities, particularly as a complement to their germplasm improvement and production systems research. Some centres, including CIFOR, ICRAF, IWMI and IPGRI were established with these as their primary concerns. Successful work has been conducted in SSA on crop and soil fertility management (CIMMYT, CIAT, IITA, ICRISAT and WARDA), *Striga* control (IITA and CIMMYT) and agroforestry management (ICRAF and IITA). A major constraint to agricultural and economic development in SSA is the economic and physical scarcity of water (IWMI, 2000). IWMI has initiated research activities in West, East and Southern Africa on catchment management, small-scale community-based irrigation, water harvesting and on the broader links of water to human health and the environment. Further, CGIAR Centres have played a lead role in using GIS to characterize production systems and for targeting research.

As concluded in various workshops in Africa and elsewhere, it is difficult to evaluate the contributions of such natural resources management (NRM) research in quantitative terms. Many of the benefits relate to losses avoided and thus making resource systems more sustainable (e.g., adoption of criteria and indicators of sustainable forest management as developed by CIFOR). These benefits become difficult to measure and attribute to research, because estimating the counterfactual situation – what would have happened without the research – is difficult. Thus, oftentimes, one has to rely on anecdotal information to indicate the potential contributions of the whole investment in research on NRM. Several centres work on soil/water/nutrient management. Examples are CIMMYT's work in Southern Africa on soil fertility management, ICRISAT's work on microfertilizer techniques using cokecaps, ICRAF's work on soil fertility and agroforestry in Eastern and Southern Africa, IITA's soil nutrient research in West Africa, and ILRI and ICRISAT's research on the broad bed maker research in Ethiopia.

Of note, also in the natural resources management area is the research contributions of ICRAF, IITA and ILRI on agroforestry and silvo-pastoral systems. Agroforestry has been practised in Africa for centuries, and there are few African farmers who do not use trees in their overall farm system, for animal fodder, fuel, shade and other uses. CGIAR Centres have initiated significant agroforestry research activities in many countries, and success is being reported in such areas as improved fallow management, tree domestication and tree management in dryland areas.

4.2 Integrated Pest Management (IPM)

One of the few examples of measured benefits of research on natural resources relates to integrated pest management (IPM). The CGIAR and its partners mounted a major programme on the biological control of the cassava mealy bug in Africa. Shortly after the pest had spread over most of the African cassava belt thereby causing significant economic losses, IITA selected and reared a natural enemy, a parasitoid wasp. During 1982, it was distributed to mealy bug infested African countries. Since 1992, the pest is controlled in most of Africa and the ecological balance has been restored. The return on this investment has been analysed in two economic studies (Norgard, 1988; Schaab, 1997). Both come to the same conclusion that even when using the most conservative assumptions, the cost benefit ratio is well over 100. Consequently, average cassava yields in SSA have steadily increased from 6.7 tons/ha during the seventies to 7.7 tons/ha in the eighties and 8.5 tons/ha during the nineties.

Zeddies *et al* (2000) also calculated the costs and benefits of the biological control of the cassava mealy bug over a 40-year period (1974-2013) for 27 African countries. They calculated that for every dollar spent on research, African farmers would gain US$ 200 over this period, giving an IRR of 261%, with a NPV of US$ 10 billion. However, Waibel (1999), an independent economist and expert in IPM appointed by SPIA to assess the impacts of IPM in the CGIAR, cautions about comparing rates of return from "crisis research" to those derived for research dealing with normal, non-crisis situations, e.g., germplasm improvement, farming systems, natural resources management in general.

Since the successful control of the cassava mealy bug, the main cassava pest has been the green mite. IITA again successfully identified effective natural predators, one of which was released in 35 African countries. IITA estimates that in Benin, Ghana and Nigeria, cassava farmers are earning at least US$ 100 more per year as a result of the research and yielding an IRR of at least 100%. IITA has further achieved impact through the work on water hyacinth and mango mealy bug. The Institute has also made major contributions to the science of biological control through the development of sound methodologies and the generic understanding of predators and preinteractions.

4.3 Agroforestry and Forestry

For the development of more sustainable production systems, IITA's research first focused on the introduction of alley farming, the combined growing of leguminous trees and food crops, whereby the trees fix nitrogen from the air and extract nutrients from the sub-soil, benefiting the food crops grown between them. Recent data show that there is a steady spread of this technology to areas where there is a shortage of land and where additional income can be generated from the trees used in the system. An IITA survey of about 1000 farmers indicated also that those who been exposed ten years or more ago to alley farming, over 50% continue to use the technology, although often in a modified form.

ICRAF is conducting other promising work on agroforestry and soil fertility that is now being widely adopted by poor smallholder farmers. This includes the use of cheap and simple methods to improve seriously depleted soils through the coherent use of indigenous rock phosphate and common shrubs. Other agroforestry technologies promoted by ICRAF include improved fallows with leguminous tree and shrub species. Tens of thousands of farmers in Kenya, Zambia and Malawi have adopted agroforestry technologies as recommended by ICRAF and its partners. ICRAF expect that by the end of this decade several million African farmers will have adopted its agroforestry and soil fertility technology packages.

4.4 Biodiversity

Genetic erosion poses a serious threat to the fragile ecosystems of SSA. IPGRI has made major efforts in strengthening national and regional capacities to conserve and sustainably use genetic resources. It is estimated that 46% of germplasm used in CGIAR germplasm research is of African origin. SINGER, the CGIAR Systemwide Information Network for

Genetic Resources reports considerable germplasm exchange between CGIAR Centres and SSA.

Collaborative research conducted with IPGRI and national partners on neglected crops has increased awareness of the importance of these crops and helped develop effective conservation strategies. Examples include integrated approaches for tuber crop conservation ranging from farmer-led approaches to cryopreservation, ecogeographic diversity studies on and collecting of wild rice in East and Southern Africa, and restoration of sorghum diversity in Somalia.

National programmes help secure the natural capital by conserving germplasm. The impact that this has directly on farmers depends on either the absorption of this material into breeding programmes, or the direct supply of material to farmers. Increasingly, national programmes are involved in on-farm management of genetic resources, often through improving use of the material. Work is underway to evaluate the impact of seed diversity fairs on varietal selection and productivity in Mali and Zimbabwe. Among concrete examples of uptake of germplasm from genebanks, it is known that germplasm from CGIAR collecting missions has been incorporated, for example, into breeding programmes at ICRISAT, at the Institut d'Economie Rurale and at the Institut Polytecnique Rurale in Mali. The CGIAR has also made substantial contributions to seed relief activities such as the 'Seeds of Hope' project in Rwanda. Such action research has been undertaken with NGO and NARS partners. The CGIAR has also promoted decentralized seed systems especially for crops not well served by the private sector.

An assessment of the advances made in national programme development in the area of plant genetic resources is in progress, using the FAO Report on the State of the World's Plant Genetic Resources for Food and Agriculture and country reports as the baseline. A refined series of indicators is also being developed for future use. In addition, an in depth study of the impact of IPGRI support on the national programme in Ghana is being carried out with the assistance of ISNAR.

Through ICLARM's project entitled "Strengthening Biodiversity and Fisheries Management ACP countries", ICLARM has established three regional nodes in Africa; in Kenya for east Africa, in Namibia for southern Africa and in Senegal for West Africa. The nodes act as focal points for regional collaboration and national partners have been trained in the use of the fisheries and biodiversity management tool FishBase (made available on CD and a website), ecosystem concepts for fisheries management, and have been provided with hardware and software to maintain coordination and linkages in the different sub-regions. Outputs have been the repatriation of data available in European museums to the participating countries in SSA and the development of fish species lists for the countries concerned.

5. Livestock

Livestock is of major importance to smallholder farmers in SSA, as a source of food, income, security, traction and soil fertility. The major constraints to increasing livestock productivity are the shortage of livestock feed, animal diseases and policy restrictions. ILRI‘s research has contributed to the body of knowledge on how smallholder mixed farming systems can be made more efficient and sustainable by planting forages, fodder trees and shrubs to feed livestock and improve soils through nitrogen fixation. ILRI has estimated that in West Africa alone, there are 27,000 adopters of planted forages based on CGIAR technology realizing more than US$ 22 million in benefits representing an IRR of 36% (ILRI, 2000).

Recent ex post and ex ante impact assessments by IITA and ILRI have also shown how the introduction of dual-purpose cowpea (for grain and fodder) can lead to both increases in grain as well as forage production while at the same time improving soil fertility through better nutrient cycling. ILRI estimates that cattle fed on cowpea produce an extra 50kg of meat/ha/year and produce manure that contains 25% more nitrogen. A recent ex ante impact assessment, which took multiple research approaches to critically examine the adoption and impact of the genetically improved cowpea varieties in the dry savanna region of West Africa, estimated rates of return to the research investment of 71%, with a benefit:cost ratio of 63:1. The new seeds offer both female and male farmers added flexibility in their farming activities and respondents cited many different types of positive impacts on their livelihoods (not all of which were anticipated by researchers) with the use of the new dual-purpose varieties, including increased food security.

ILRI reports that in Eastern Africa, in particular Ethiopia and Kenya, thousands of smallholder dairy farmers have also increased their productivity and profitability through research-based technologies developed through collaboration between national and international research systems. Market-oriented smallholder dairy production offers opportunities for diversification from traditional export crops, particularly in light of expected rapid growth in milk consumption in SSA. Higher-producing grade and crossbred dairy cows are a central component of efforts to promote intensification of dairy production in many regions, including Eastern Africa. ILRI and partners are quantifying the positive impacts of more intensive dairying for smallholder households. For example, a recent study in coastal Kenya showed that for each cow owned income increased by 80% compared to the mean total income of non-adopting households. Such information is key to understanding the factors driving smallholder dairy evolution, thereby improving rural development support to large numbers of smallholders in the region.

While the impact of ILRI's work on improving animal health at the farm level is limited at present, major advances are being made in research on the genetics of disease resistance. Significant progress has been made in respect of tolerance to trypansomoses which are most prevalent in Africa but spreading in Asia and Latin America. Similar advances have been made in respect of genetic resistance to internal parasites, which is a growing animal health and environmental problem in all livestock production systems.

The assessment and conservation of existing biodiversity of plants and animals employed in agriculture is paramount for sustainable development. The genetic material underlying that biodiversity of indigenous animal species that most people in the developing world rely upon for meat and milk is being characterized by ILRI’s genetic resources programme. An integral component of that effort involves a first attempt to value indigenous animal genetic resources. Without such a valuation, it will be impossible to assess the impact of research and conservation efforts aimed at stemming the loss of genetic material that contributes towards hardier, more resilient, and disease resistant animals. ILRI has also assembled a collection of 13,000 forage accessions from which thousands of best-bet accessions are distributed annually for testing, multiplication and utilization in smallholder farming systems.

6. Fish

Since the mid 1980s, ICLARM has conducted work on the introduction of aquaculture into farming systems of southern Malawi which has an agroecology common to large parts of southern Africa. Communities exist which traditionally eat fish from the local lakes but the size and quality of catches from capture fisheries are in decline (from 88,588 tonnes in 1987 to 56,000 tonnes in 1997). ICLARM has demonstrated the advantage of the introduction of pond aquaculture into farms and has augmented awareness of the benefits of recycling farm nutrients and wastes. Adopting farmers have been shown to benefit from the existence of on-farm water resources, nutrient efficiencies, on-farm fish consumption and sale and, particularly, the additional nutritional and cash benefits derived from farmers' ability to plant vegetables at the pond borders. In 2000, ICLARM started to extend these technologies (in collaboration with the knowledge of local farming systems provided by IITA) to Cameroon, an example of the high potential agroecology of humid West Africa.

Of Malawian farmers who have been exposed to integrated aquaculture technology, 86% have adopted at least one of the demonstrated technologies, 76% adopted at least two, and 24% adopted four (Brummett and Noble, 1995). In addition, the adoption is sustained over time. All of the farmers with whom ICLARM has worked who have access to permanent water supplies are continuing to grow fish and improve their production. Among those farmers with only rainfed fishponds, 36% dropped out for one reason or another (40% of those dropping did so because of family deaths or illness rather than for any agricultural reason), but those remaining also have continuously improved their ponds and production.

7. Policy

Food and agricultural policy research impacts poor people in developing countries in four main ways. First, good policy research illustrates the critical link between the right kinds of investment in agricultural production and distribution and the widespread alleviation of poverty and the improvement of environmental sustainability. Second, policy research is conducted to fill critical gaps in understanding how to promote the production and distribution of crops, livestock, trees and fish important for the poor. Third, policy research strengthens analytical and decision-making capacity through collaboration across countries of researchers and policy analysts concerned with specific food and agricultural policy issues critical to welfare in developing countries. Fourth, policy research cuts the risks of decision-making for policy makers in developing countries by illustrating the costs and benefits of different food and agricultural policy options. These functions are especially beneficial to helping the poor in Africa. (IFPRI, 1999)

Donor partners as well as some African governments have in recent years pulled back from supporting technical and institutional change in the agricultural sector, as they have not had a clear view of the contribution of investment in agriculture to poverty alleviation, overall economic growth, and improved sustainability of the rural environment. IFPRI has addressed this over the years with a series of strategic studies in Senegal, Burkina Faso, Niger, Zambia, South Africa, Madagascar and Tanzania showing that it will be very difficult to alleviate poverty and hunger in many African countries without renewed commitment to improving agricultural production by smallholder farmers, and that such investment is in fact effective at creating increased employment.

Several countries, such as Ethiopia, Mozambique, Sudan and Malawi, have been able to implement a much improved food and nutrition monitoring system as a result of CGIAR policy research. This has helped the governments of these countries to respond to famine, food and agricultural crises. It has also increased the analytical and decision making capacity in governments, research institutes, and at universities.

Policy research on individual CGIAR commodities such as on livestock, milk, fish, cassava, rice and maize, has also contributed to the understanding of major policy constraints to the improvement of these important good. Adesina *et al* (1999), for example, found that policy constraints were the main limitation to adoption of alley farming. Since the devaluation of the CFA, adoption of alley farming has expanded rapidly across West Africa. ILRI has also conducted interesting policy research on peri-urban dairying and dairy policies.

IFPRI has worked closely with many partners in conducting policy research on pricing, marketing and food security strategies in several African countries. For example, the Institute has worked with researchers in Benin, Malawi and Madagascar to assess the impact of agricultural market liberalization on smallholder farmers' production and income patterns, their access to agricultural markets, and the behaviour and performance of these markets. The results of these studies can be used by policymakers to identify the types of policies and investments needed to improve agricultural production and marketing in these countries.

For a number of years, IFPRI has worked in Southern Africa on issues of macroeconomic reform and regional integration, including analysing the impact of various international trade agreements. As part of that work, IFPRI has developed data systems for a number of countries integrating the national accounts, trade data, and household data.

These studies have examined the economy-wide effects of alternative policy reform options, particularly those affecting poverty reduction and equity. Trade liberalization alone may increase national income due to the reallocation of resources toward higher productivity sectors, but it can worsen income inequality if poor households do not have ownership of these resources. Trade policy and domestic household food security policies must be linked. Failure to undertake complementary policies helps explain why trade liberalization efforts in many African countries have not contributed significantly to egalitarian growth and poverty reduction.

In Mozambique, IFPRI field-based researchers and the Ministry of Planning and Finance completed a poverty assessment report -- the first nationally representative study that considered both rural and urban areas. IFPRI researchers worked side-by-side two ministry staff and four university students to complete the report, which not only built significant capacity for future policy research in the country, but created ownership and acceptance of the study's results. The latter result was important given the somewhat politically sensitive results of the assessment. The Government of Mozambique requested follow-up assistance from IFPRI to develop poverty action plans at the provincial level.

Spending on emergency relief in Africa has increased dramatically during the last ten years. In some countries, this has been matched by a decrease in resources available for development assistance. In Zimbabwe, IFPRI studied the trade-offs between relief and development. The study found that had resources from drought relief in 1994-95 been reallocated to capital stock and extension in 1992-93 for the same households, poverty rates would have been lower in both the drought and the non-drought years. In other words, poverty reduction is enhanced more by development assistance than by crisis aid. These findings indicate that during disasters, relief aid should be supplemental not a substitution for development assistance and its objective should be to enhance livelihoods and not simply to protect lives.

IFPRI is attempting to understand the causes of land degradation and its links to poverty and agricultural productivity in the East African Highlands. Specifically in Uganda and Ethiopia it is examining strategies for sustainably intensifying agriculture in several important types of less-favoured lands. Heavy emphasis is given to building the capacity of local collaborators.

Research by IFPRI and its collaborators on the causes of and solutions to famine in Africa has led to general acceptance that famine is only partially the result of natural disasters and more the result of bad policies. This has led to greater understanding of the policies and projects required to prevent famine and mitigate its consequences. In Ethiopia, these research results led directly to the government's adoption of a strategy for famine prevention, which emphasizes employment opportunities rather than food handouts.

IFPRI research on employment-generating public works programmes contributed to decisions by the governments in Niger, Botswana, Tanzania, and Zimbabwe to integrate labour-based public works programmes into national planning for both drought relief and infrastructure creation. In Ethiopia, IFPRI conducted research on the food security impact of the country's large food-for-work programme. This research convinced donors and the government to focus less on quantifying the programme's success on the enumeration of physical outputs but on maximizing the benefits of income transfers to the poor through improving participation in project design and other complementary projects.

WARDA has contributed to the assessment of the impact of agricultural policy reform on rice sector competitiveness in five West African countries through the provision of training and technical backstopping to Planning Bureaux and Agricultural Policy Units of Ministries of Agriculture. CIFOR has also contributed by influencing global and national forestry policies and ways of thinking about forestry issues. Recent developments in international legal and policy area have significantly changed the policy environment related to genetic resources. IPGRI has produced and distributed research reports, analytical papers and decision-making tools to provide policy-makers with the technical underpinnings for sound policies for conservation and exchange of genetic resources and in particular biodiversity. In a recent example, IPGRI helped sponsor a workshop in Zimbabwe for African policy makers on genetic resources, intellectual property rights and access in the context of the WTO/TRIPS agreement.

Intergovernmental bodies are debating issues related to genetic resources and developing international agreements to govern them. The results of these negotiations can have profound affects on the conservation and use of genetic resources in SSA. IPGRI monitors relevant international fora, including the CBD, WTO/TRIPS, UPOV and the International

Undertaking and provides input on behalf of the CGIAR through background papers, presentations and seminars to help promote agreements that support sound genetic resources management and conservation.

8. Capacity and Institution Building

Capacity and institution building in the CGIAR aim at strengthening skills in specialised areas of science, improving research management and the planning and implementation of science (ISNAR, 2000). The importance of strengthening Africa's institutional environment and how to go about this has been discussed by Eicher (Eicher, 1999). Between 1970 and 1996, the last year for which compiled data are available, nearly 17,000 African scientists have benefited from CGIAR training activities. Most of these (12,243) attended group courses. The remainder participated in the Centres' personal development schemes through collaborative research of various kinds such as technical associates, research fellows and graduate fellows. During the recent years, training has increasingly evolved to more decentralised training and training of trainers, among other new forms, allowing for larger numbers of trainees to be reached. The total number of African scientists trained by the CGIAR can now be estimated as being well over 20000. Since 1991, the CGIAR Centres have strengthened their training-related initiatives in SSA by working together in the IARC/NARS Training Group (INTG).

The distribution of African trainees by year, type of training and centres is indicated in Tables 4 and 5 and in Figure 5. The activities of the CGIAR in the field of training have no doubt contributed to capacity building of African NARS. A SPIA/TAC study on the impact of these activities is currently underway. In addition to training, CGIAR activities in the fields of networking, organization and management, information, documentation and publication have also contributed substantially to capacity building. A large number of regional and thematic research networks in all areas of agriculture, forestry and fisheries are being supported or coordinated by the CGIAR. The CGIAR has also engaged in strong partnerships with regional organizations such as ASARECA, SACCAR and CORAF.

In addition to making training modules available to research institutes, non-governmental organizations, and other educational establishments, ISNAR has spearheaded a long-term, intensive program of agricultural research management training in sub-Saharan Africa. During 1996– 1999, 46% of ISNAR training events were held in Africa. An eight-year programme to strengthen southern Africa's training capacity, conducted in partnership with the Southern Africa Development Community (SADC) and the Eastern and Southern Africa Management Institute (ESAMI), helped establish or strengthen training units in some 20 agricultural research and training institutions within the region. Most of these training departments continue to base the research management components of their in-service training on materials they developed in collaboration with ISNAR.

Overall, ISNAR worked in 39 countries of SSA and assisted countries such as Uganda, Kenya, Rwanda, Tanzania, Benin, Ghana, Mali, Burkina Faso and Senegal in the development of master plans and helping to strengthen research management.

Another cooperative initiative to build capacity, through training, among African research managers is the "IARC/NARS Training Group". Participants in the programme, 30% of whom are women, build skills in four key areas of research management: leadership, financial management, research programme formulation, and planning, monitoring, and evaluating research projects.

The IARC/NARS Training Group now trains more leaders in research management than any other training programme on the African continent. Participants are putting the skills they acquired to good use. Gambian participants, for example, are implementing a participatory priority-setting process. Nigerian participants applied techniques they learned for client evaluation in research programme formulation. In Burkina Faso, managers are using approaches they learned in formulating research programs for INERA, the country's main public-sector agricultural research institute.

IITA and WARDA have played a lead role in providing capacity strengthening activities in West Africa. WARDA channels these activities through Task forces and other collaborative mechanisms. Its capacity strengthening efforts have contributed to improve policy analysis capacity in the region and the training activities have given the Association visibility within its mandate area and facilitated research dissemination and technology transfer. Electronic connectivity of NARS has been improved through the AfricaLink project, in order to strengthen information exchange and management within West and Central Africa and the rest of Africa and the world.

Over the years, IITA has devoted a considerable amount of its resources to addressing the human resource needs of national agricultural research systems in SSA, from many angles. IITA's group training activities have benefited nearly 7000 researchers and technicians since 1970. Demand-driven training, steered by the needs of regional networks, focuses resources where they are most required. Courses have had other beneficial spin-offs. A network linking soil and plant analytical laboratories across Africa, SPALNA, arose from an IITA course for soil and plant analysis laboratory managers. Training courses are supported by IITA-produced training materials, which are also widely disseminated to researchers, trainers and trainees, and extension workers across the region. In addition, more than 800 graduate students have obtained masters and doctorate degrees through IITA supervision since 1970. IITA provides further research support skills for these students in areas such as biometrics, science communication, grant proposal writing, and research management.

IITA's resident scientist scheme (country projects in Cameroon, Ghana and Mozambique) has enhanced the NARS capacity to conduct on-farm research to determine research priorities and to prepare strategic plans for agricultural research. IITA has channelled capacity-strengthening work also through networks. As an example, the SAFGRAD commodity networks (terminated in 1993) had substantial impact on research on maize and cowpea in West Africa. Also, the networks EARRNET and AFNETA have facilitated the strengthening of human resource capacities of the participating NARS, and encouraged on-farm and farmer-participatory research. The AFNETA network was evaluated to have largely been successful in developing strong institutional linkages between IARCs, NARS, donors, cooperating institutions and extension organizations. Furthermore, farmer interest in adopting new varieties and improved technologies has been strongly enhanced by networks in some cases.

CIAT has catalysed the development of bean research networks in Africa that have achieved economies of scale and a division of labour for mutual benefit among national research programmes. These fully self-governing networks now have African coordination, a fully developed research plan, and a programme of competitive research contracting. These networks are largely responsible for the rapid progress achieved in the diffusion of new bean varieties among countries.

The institutionalization of participatory research methods to more effectively link national programme research to the real problems of farmers has been a major impact. Through training and methods testing, participatory techniques have been introduced to national programmes in Ethiopia, Kenya, Madagascar, Rwanda, and Uganda. Over 200 researchers have received training in these techniques that have been utilized in more than 100 communities.

IPGRI has contributed substantially to strengthening of national capacity in the management of genetic resources. For example, over the last three years alone, IPGRI organized, coordinated, or supported training of 248 national programme staff from 21 SSA countries on plant genetic resources. CIFOR and ICRAF contributed to institution strengthening in forestry research and ICLARM in research in aquatic resources.

IFPRI undertakes training of policy analysts at ministries and universities. Through long-term collaboration with the Bunda College of Agriculture in Malawi in the nineties, IFPRI has conducted six training courses for over 110 Malawian policy analysts and a regional training for 30 participants from Southern Africa. In addition, the Institute has supported the development of the curriculum for the Bunda College's graduate level programme on policy analysis. A modified version of the Bunda-model of capacity strengthening has been implemented in Mozambique and Ghana. The Bunda College graduate-level programme and the Policy Analysis Training Programme are now fully functional and independent of IFPRI financial and technical support.

IFPRI and its collaborators established the 2020 Vision Network for East Africa in 1998. Through research, publications, training, and dialogue between policymakers and researchers, the Network is building the capacity of East African researchers to undertake policy research and generating information that policymakers can use to improve policies. To assure that the Network remains relevant and sustainable, IFPRI is partnering with a regional network, the Eastern and Central African Programme for Agricultural Policy Analysis (ECAPAPA). The project design is intended to encourage country-level ownership of the Network, including the research priorities, which have been identified for each country by teams of policymakers and researchers. A competitive grants programme supports research on country priorities; in the first round in 2000, 27 proposals were submitted of which 10 are being supported. IFPRI provides technical and methodological assistance but the research is wholly undertaken by East African researchers. A pilot programme to support young researchers completing their Master's degree has been launched. A regional research project cutting across the Network countries is under development and will involve collaborative research between researchers in each of the Network countries and IFPRI researchers. Communication instruments such as policy briefs and discussion papers are being developed, and workshops and meetings to facilitate informed dialogue on topics of priority to policymakers are being organized. While the impact of these Network activities is difficult to assess at this early point, an external reviewer of the 2020 Vision Initiative in 1999 found that a foundation is being laid for potentially significant future gains from increased utilization and empowerment of human resources in food and agricultural policy in East Africa.

The African livestock research community has so far has been the main target of ILRI's capacity strengthening efforts. As a legacy from its predecessor institutions ILCA and

ILRAD, ILRI has a long-standing record of training, which has contributed significantly to human resources development in the field of livestock research in African NARS. Between the three institutions, well over 3000 scientists have received training. Kenya and Ethiopia have particularly benefited from the training. Networking has been ILRI's principal strategy for strengthening the capacity of NARS in SSA. The networks have been able to strengthen linkages between livestock research scientists in SSA and to generate scientific information that complements national research programmes. Participation of the networks in characterisation and evaluation of forage germplasm from the ILRI genebank, has contributed to the adoption of some of the forages by farmers in several countries.

Agroforestry research has benefited from the training and organizational inputs of ICRAF. Working with national agricultural and forestry groups, ICRAF has contributed directly to the establishment of viable agroforestry institutions in many countries of the region. These in turn have developed farmer participatory research that has led to some significant advances in tree management in African farming situations. ICRAF's capacity strengthening activities have had impact in the national level, particularly through regional networks, in helping to get agroforestry integrated into a number of NARS, NGO, and university programmes in the tropics, in assisting ministries to integrate ICRAF generated concepts and ideas into national programmes and policies.

The CGIAR has also released a large number of publications and information materials on SSA. A substantial share of these has been co-authored with NARS scientists. In the case of ICRAF, for example, 40% of its publications were co-authored with national scientists.

IPGRI has played a pivotal role in institutional development and elevation of the plant genetic resources agenda in national government systems. National programmes in plant genetic resources have been developed and institutionalized in several countries in SSA through both gradual and specific interventions emanating from the catalytic mode of scientific assistance. In the last three years, coordinating workshops on national plant genetic resources have been held in 21 countries in the region. These workshops and high-level meetings, as well as scientific backstopping, have led to the initiation, establishment or strengthening of national plant genetic resources programmes.

For instance, after a policy level workshop in Uganda, a national programme on plant genetic resources was formally established and an operational budget allocated. Similarly, after a national workshop in Gambia, a national programme was established under the auspices of National Agricultural Research Institute (NARI). The establishment of such programmes is often a culmination of several varied types of interventions, which differ from one country to another and often range from public awareness, joint project development, provision of facilities to different types and levels of training of staff.

IPGRI is currently working closely with FAO to establish a system to monitor national programme development in the area of plant genetic resources, using the FAO Report on the State of the World's Plant Genetic Resources for Food and Agriculture and country reports as the baseline. This work includes developing a refined series of indicators for future use.

Networking is thought to be a mechanism by which agricultural research can be more efficiently and effectively carried out, particularly in Africa where resources are limited. The CGIAR centres are involved in supporting and participating in approximately 29 networks in the region (SGRP 2000). Centre involvement varies from network to network, with centres serving as technical advisors or members or playing stronger leadership roles such as coordinating institution or steering committee member. For example, three sub-regional plant genetic resources networks, SPGRC, EAPGREN and GRENEWECA for Southern, East, and West and Central Africa respectively, have been established with strategic support from IPGRI. IPGRI is also coordinating the Lusophone Initiative for the Portuguese-speaking countries of Africa (Mozambique, Angola, Guinea Bissau, São Tome and Principe, and Cape Verde).

Two banana and plantain networks have been established; MUSACO in West and Central Africa and BARNESA in East and South Africa. These networks come under the auspices of regional agricultural fora and are coordinated by the INIBAP programme of IPGRI. Their activities have led to the collection of baseline information on banana research and production for the development of regional research strategies. Through INIBAP projects, targeting rural smallholder farmers and peri-urban populations in SSA, the conservation, evaluation and use of banana germplasm have increased and integrated pest management technologies have been developed. In 2000, the Ugandan Government invested its contribution to the CGIAR in an INIBAP-coordinated project on the improvement of bananas, specifically East African Highland varieties, using novel techniques. Plans involve establishing a regional centre of excellence in biotechnology in Uganda.

9. Concluding Observations

The information presented in this paper suggests that the CGIAR and its partners have made major contributions to the sustainability, productivity and output of the key food crops and production systems important to the poor in SSA, to conserving biological diversity and enhancing integrated natural resources management in general, to improving policies and to strengthening the capacity of national research programmes. Progress is most notable and best documented in crop improvement efforts, where the expanding use of modern varieties has led to major increases in yields especially during the last decade. After an initial timelag, there appears to be a strong momentum now in obtaining payoff from investments in germplasm improvement research. Results are emerging in natural resources management research, and the work on biological control of cassava mealy bug has shown to have had especially high returns. Activities in biodiversity and policy research have also filled critical gaps in knowledge. The CGIAR has also contributed to scientific capacity building and institution strengthening through its training of more than 20,000 African scientists, networks and collaborative research programmes. Studies that evaluate the impact of this research on the broader CGIAR goals of poverty reduction and sustainable food security are in progress.

Despite these contributions of the CGIAR and its partners in stimulating agricultural development in Africa, there is still widespread food insecurity and poverty in the region overall. SSA is unusually heterogeneous in terms of agroecology, culture, politics and economics. Successes in many countries are masked by declines in others, often due to war or drought. Food availability per caput remains constant and African countries, in general, have not been able to sustain the rates of agricultural growth necessary to spur economic growth. While agricultural production and yields have increased, the gains made are not sufficient to meet the expanding needs of a rapidly growing population. Further, although many farmers now make use of modern varieties, often they do not have adequate access to the inputs needed to achieve higher yield potentials. Policy research is crucial to helping policy makers create the enabling environment in which farmers can exploit the full potential of technology and better protect their natural resources. But the constraints remain large, especially given the poor infrastructure and weak markets and institutions. Greater attention will have to be given to the social and institutional issues related to improved natural resources management, and to research on improved technologies for low-external input farming systems.

These observations reinforce the need for a regional approach to research planning and implementation for the CGIAR and its partners. This approach needs to be multisectoral and to involve a broad range of research and development partners. The key to agricultural development is the recognition of the need for complementarity of efforts. Improvements in technology or sustainability will not have a lasting impact unless there is access to markets, institutions, policies, inputs and infrastructure. If the proposed regional approach to research is successful, this message of hope could become one of excitement.

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ANNEX 1 - TABLES AND FIGURES

Table 1: Modern Variety Diffusion 1970-98 in SSA
(% Area Planted to Modern Varieties)

	1970	1980	1990	1998
Wheat	5	22	32	52
Rice	0	2	15	40
Maize[1/]	1	4	15	17
Sorghum	0	8	15	26
Millets	0	0	5	14
Beans	0	0	2	15
Cassava	0	0	2	18
Potatoes	0	25	50	78
All Crops	1	4	12	26

Source: Evenson and Gollin (Eds). 2001

[1/] According to the latest CIMMYT impact report (in press), 47% of the area planted to maize in all of SSA (including South Africa) was planted to modern varieties in 1998. The regional figures are 36% for Western and Central Africa and 53% for Eastern and Southern Africa.

Table 2: Crop Genetic Improvement Contributions to Yield Growth by Regions

						CONTRIBUTION SHARES			
						Adoption (1998)		Varieties (1965-2000)	
REGION	**1960s**	**1970s**	**1980s**	**1990s**	**1960-98**	**IX**	**IA**	**IX**	**IA**
Latin America	.312	.600	.781	.751	.658	.28	.30	.39	.18
Asia (including China)	.452	.932	1.030	.890	.884	.30	.37	.18	.39
Middle East-North Africa	.141	.270	.681	1.228	.688	.51	.31	.62	.28
Sub-Saharan Africa	.017	.142	.358	.497	.280	.44	.27	.45	.28
All Regions	.321	.676	.832	.823	.718	.35	.34	.36	.19

IX: Varietal cross made in IARC programme
IA: Varietal cross in NARS programme with IARC assistance

Source: Evenson and Gollin (Eds), 2001.

Table 3: Average yields, harvested area, and production of major food crops in SSA

	Average Yield, ton/ha					Harvested Area, 1000 ha					Production, 1000 ton				
Crop	**1960s**	**1970s**	**1980s**	**1990s**	**2000**	**1960s**	**1970s**	**1980s**	**1990s**	**2000**	**1960s**	**1970s**	**1980s**	**1990s**	**2000**
Maize	1.1	1.4	1.3	1.4	1.5	15,785	17,485	21,073	24,540	24,106	17,087	23,655	27,772	34,566	37,225
Sorghum	0.7	0.8	0.8	0.8	0.8	13,977	13,884	18,061	22,762	21,847	9,942	10,591	14,569	18,487	18,364
Millet	0.6	0.6	0.7	0.6	0.7	12,217	12,887	13,532	19,132	20,035	6,809	7,966	9,601	12,233	13,691
Wheat	0.7	1.1	1.3	1.7	2.3	2,598	3,069	3,073	2,917	2,321	1,873	3,369	4,030	4,845	4,172
Rice (paddy)	1.3	1.4	1.5	1.6	1.6	3,075	4,135	4,782	6,736	7,053	3,976	5,633	7,399	10,867	11,397
Cassava	5.9	6.7	7.7	8.5	8.5	6,189	6,938	7,798	10,189	10,805	36,241	47,574	59,530	87,003	91,451
Potato	7.4	7.8	8.1	8.5	9.2	198	331	420	516	629	1,470	2,580	3,409	4,406	5,795
Pulses	0.4	0.5	0.5	0.4	0.4	8,710	8,796	9,350	14,520	16,365	3,565	4,277	4,533	6,342	7,079

Source: FAO (2001) WAICENT on-line database. Sub-Saharan Africa includes Republic of South Africa
The values are three year averages centered on the 6th year of each decade, e.g. 1965-67 averages, except for 2000 that is a single year's value

Table 4: Number of African Scientists Trained at CGIAR Centres

Year	No. of Trainees	Total No. of Trainees (Total of 5 Years)	Year	No. of Trainees	Total No. of Trainees (Total of 5 Years)
1970	4		1985	1242	3908
1971	31		1986	1263	
1973	47		1987	1057	
1974	128	307	1988	907	
1975	97		1989	893	
1976	114		1990	920	5040
1977	171		1991	930	
1978	328		1992	1005	
1979	291		1993	989	
1980	409	1530	1994	1067	
1981	491		1995	796	
1982	693		1996	602	5389
1983	798		1997	112	(record incomplete)
1984	684				

Source: ILRI. CGIAR Training Database for SSA

Table 5: Number of African Trainees by Type of Training

Type of Training	No. of Trainees
Not known	445
Graduate Fellows	868
Group Course	12243
Industrial Attachment Associate	278
Research Fellow	544
Senior Research Fellow	60
Student Associate	27
Technical Associate	2036
Visiting Scientist	63

Source: ILRI. CGIAR Training Database for SSA

Figure 1: Growth of Total Food Production by Developing Region (Calories/year)

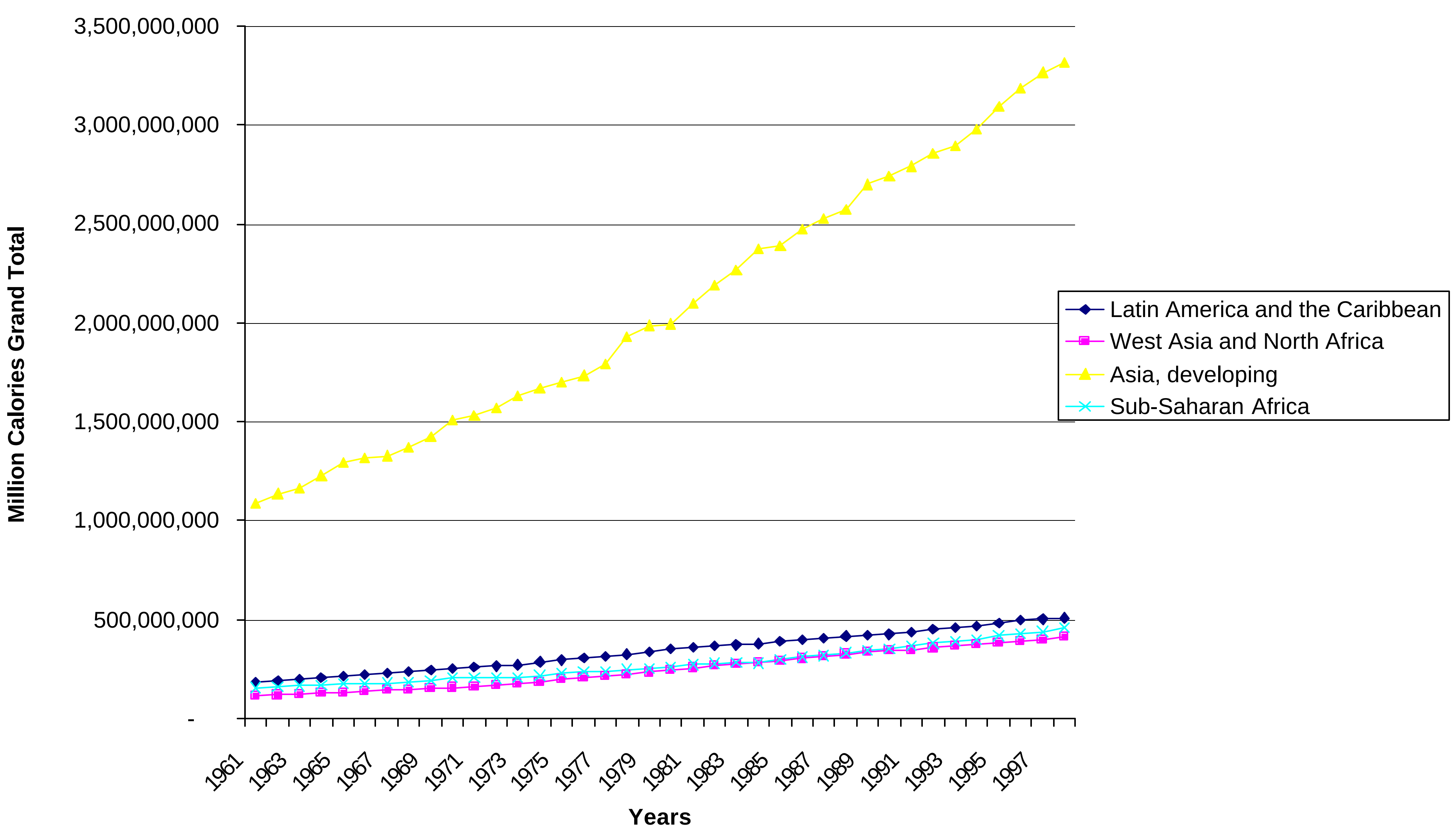

Figure 2: Gross Production Index Number for Agriculture by Developing Region

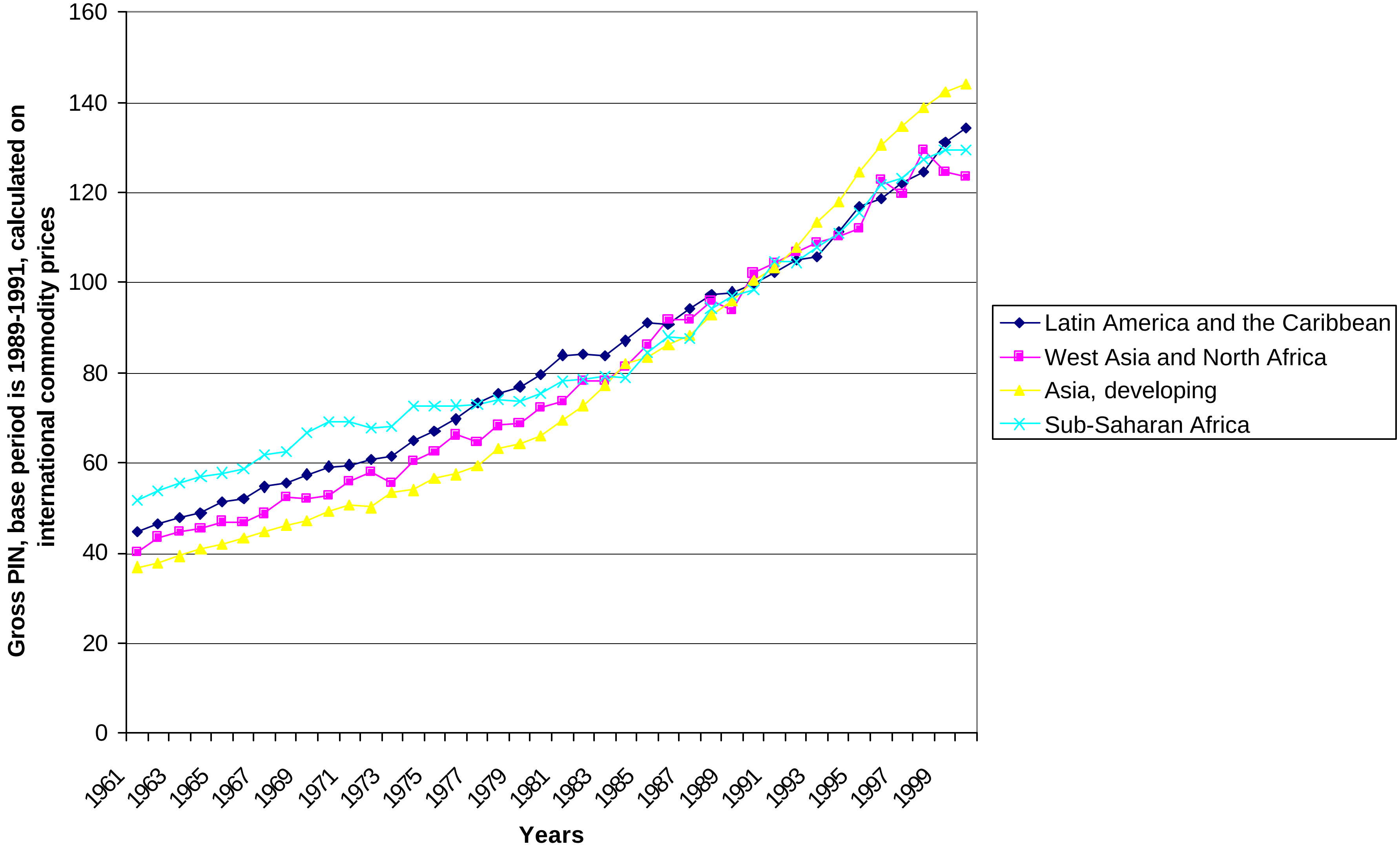

Figure 3: Food Availability per Caput by Developing Region

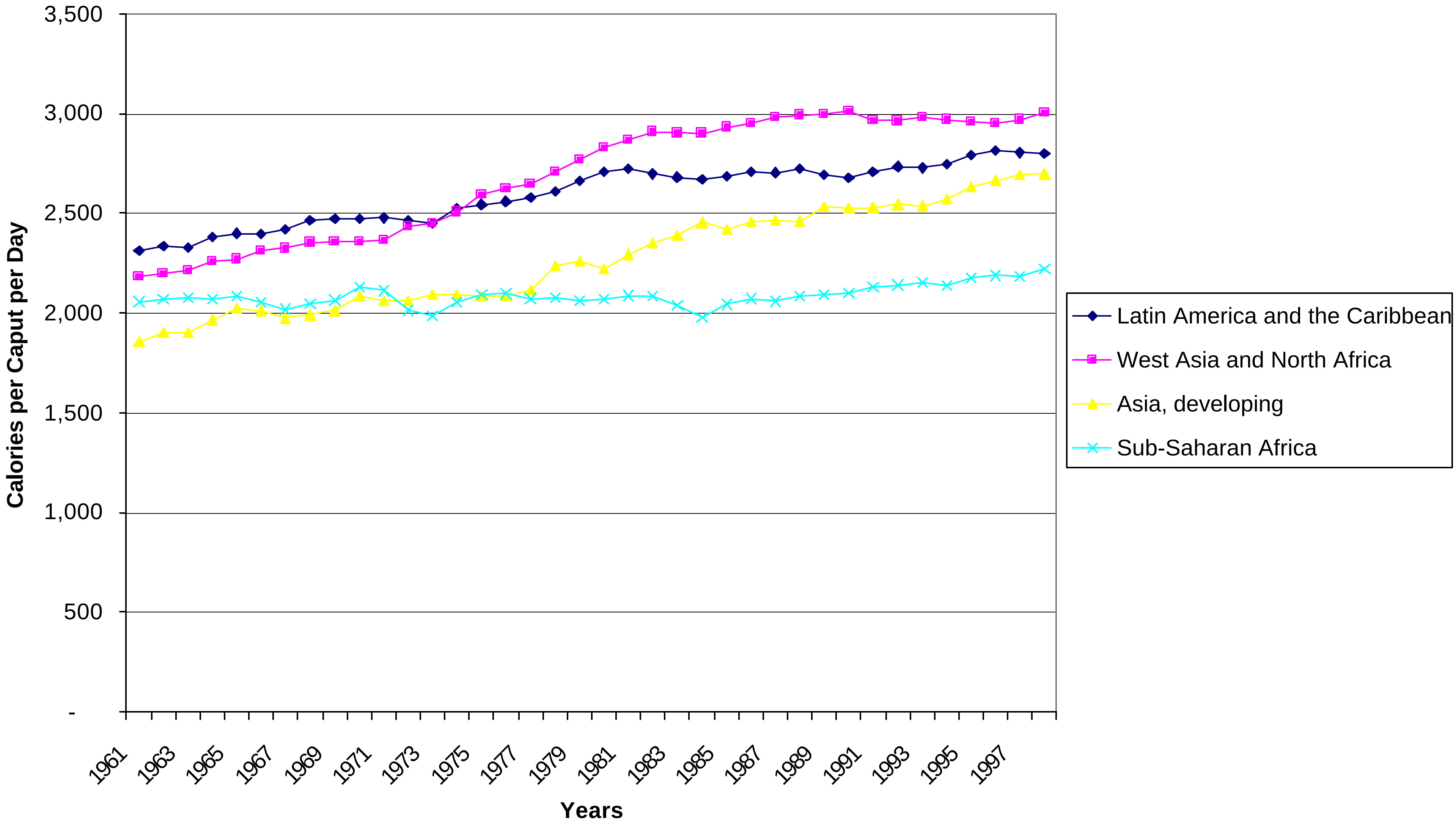

Figure 4: Gross per Capita Production Index Number for Agriculture by Developing Region

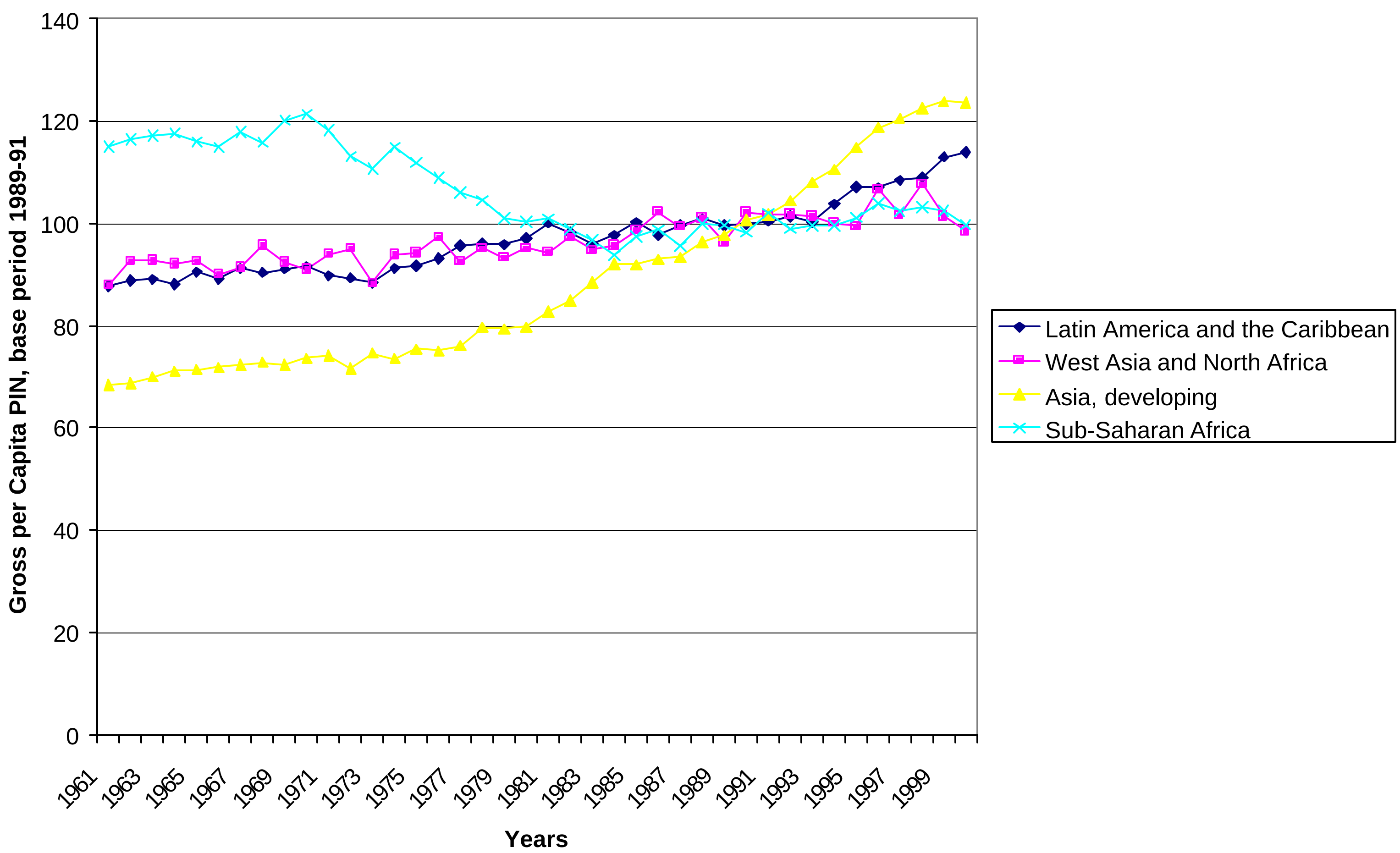

Figure 5: SSA trainees from CGIAR Centres during 1970-96