Monitoring Crop Production From the Ground

The main functions of an early warning (EW) system are to provide the earliest indication possible that food supplies may be limited and to determine where and to what degree households dependent on agriculture will become vulnerable. Satellite imagery is one of the types of evidence that are available earliest for monitoring the agricultural production season, but its limitations require that it be combined with a careful ground monitoring of the crop season to achieve an accurate early assessment of agricultural production. The purpose of this workshop discussion paper is to provide basic information on indicators of the quality of crop production (section I), guidance on gathering information on the status of crop growth during field visits to important areas of agricultural production (section II), and suggestions of potentially useful networks for information gathering that are available in most FEWS countries (section III). The paper indicates questions to ask and sources of information to exploit so that potentially useful EW information will not be missed.

Section I. What To Keep in Mind in Monitoring Crop Production

A. Introduction

This overview, the workshop presentation, and the accompanying handouts provide (1) a list of elements to keep in mind when monitoring the crop season and (2) the related background information on factors that contribute to good agricultural production. They are organized chronologically, starting with the pre-crop-season period and going through the postharvest period. Although this discussion is based, essentially, on the production of cereals, many of the ideas presented apply to the production of legumes, roots, and tubers and other annual cash crops, such as cotton. Most of the principles discussed apply to the low-input farming that is practiced throughout much of the FEWS world. Fortunately, these principles can also be applied to the high-input agriculture practiced in areas of several FEWS countries.

Production, Area, and Yield

An important relationship to keep in mind when monitoring agricultural production—and while reading the rest of this paper—is the following:

PRODUCTION = AREA HARVESTED × YIELD;

where **production** is expressed in metric tons; **area harvested,** in hectares; and **yield,** in metric tons per hectare. This relationship is useful in that it allows us to see that high **production** is dependent on having a large **area harvested** or high **yields** or both. This concept will be used throughout this paper to classify factors into those that affect the **area harvested**—often by affecting the **area planted**—and those that affect the **yields**, that is, the amount of production per hectare. For example, while government policies, market forces, and the most severe droughts and predator attacks can affect the **area harvested**, most of the factors that we monitor after the crops are planted—such as rainfall, development of the vegetation, and fertilizer use—are factors that affect **yields.**

B. Prior to the Cropping Season

Understanding Local Planting Decisions

Farmers around the world make their planting decisions before the season starts, by weighing the resources available to grow their crops against the returns that can be expected from their production. For a corn farmer in the United States, this may be essentially an economic decision, based on reliable cost and price information; for the small-scale African farmer, the decision may have to be made without being sure of the availability of credit, fertilizer, seed, labor, and marketing channels. In many subsistence farming systems the only resources available may be seed from the previous year and family labor, and the returns may be barely enough grain to feed the family. An understanding of the role and availability of these elements for a given country, region, and crop can lead to an early indication of the **area** that is likely to be planted in each crop as compared with other years. In addition, a determination of the level of inputs available may give an indication of whether **yields** can be expected to be higher or lower than normal—all other factors (see below) remaining constant.

Staying Abreast of Agricultural-Sector Dynamics

As with all FEWS monitoring, the availability of information on these early indicators of crop production will vary from country to country and year to year. As a result, FFR's are well placed to know where to get this information and to judge its reliability. It is important to determine if agricultural programs (often stimulated by the International Monetary Fund, the World Bank, or bilateral donors) will be in place in time to affect farmer decisions on the **area** to plant and level of inputs (which affect **yields**) that will be used.

Not only will central and local government or donor policy affect planting decisions, but parastatals responsible for different commodities or regions, farmer commodity groups or cooperatives, and NGO's may also have significant changes in their policies or programs that may encourage or discourage production of a given commodity. It is clear that FFR's cannot maintain contacts with all such agencies, so it is important to maintain a secondary source for the information that these agencies can provide or to develop linkages with a few of the most important organizations.

The movement of refugees or other displaced groups onto or off of good agricultural land, the redistribution of good farming land to different population groups, the opening of new land due to irrigation schemes or onchocerciasis eradication, and, unfortunately, civil war are examples of factors that may affect the **area** under cultivation.

Agricultural Programs From the Farmers' Perspective

The best approach to understanding the effect of policy changes on planting decisions is to investigate from the farmers' perspective—the one that really matters. As planting time arrives, are there seeds of improved varieties, fertilizers, planting tools, means of land preparation, credit, and information accessible at the farm level? If so, maybe maize **yields** can be expected to be as high as 4 to 5 MT/ha rather than the 0.5 to 2.0 MT/ha that can be expected from the traditional technologies. This source of information is obviously better than policy-level information, but it may require either travel to key areas or reliance on a network of agricultural extension agents or NGO's, for example, if it is not already being collected and made available to the FFR.

C. From Land Preparation Through the Vegetative Period

Determining the Effects of Rain on Crop Production

While FEWS, in general, does an excellent job of monitoring the weather through remote sensing and local weather and rainfall reporting, a better understanding of how these weather phenomena are affecting crop production will improve our analysis and reporting. Once planting[1] plans have been made, the weather as it affects soil moisture, evapotranspiration[2] and crop growth now starts to have its critical and highly variable effect on crop production.

Determining the Start of the Rainy Season

In the majority of cases—where there is a distinct dry season and the new cropping season begins with the onset of rains—the **area sown** will depend on the timing and intensity of the current season's rain. In general, the earlier a threshold amount of rain (for example, 20 mm for sorghum and millet farmers preparing the land with a hoe on the lighter soils of the Sahel) has fallen after a critical date, the earlier sowing begins and the greater the area that can be sown. Many factors can complicate the sowing. Most important, is an interruption in the "start of the rainy season" that will cause a suspension of sowing activities, or worse yet, require resowing fields rather than moving on to new ones.

Knowing How Late Sowing Affects Yields

Yields are also affected by delays in sowing, the quality of the seedbed that was prepared, and the conditions under which the crop is sown. The degree of the negative effect of late sowing—and resulting reduction in the length of season—will vary, depending mostly on the crop species, the variety used (whether or not it is day length sensitive[3]), and the conditions throughout the

[1] **Planting** is a good generic term, but for cereal crops, which are started from seed placed directly in the field, **sowing** is more accurate.

[2] The evaporation of water from plants is called **transpiration**. Evaporation from soil and transpiration combined are called **evapotranspiration.**

[3] **Day-length-sensitive** varieties are those whose flowering is triggered by the length of the day and thus occurs at a predictable time during the year. **Day-neutral** varieties depend on temperature for flowering and maturation.

rest of the season. For example, a late-sown day-length-sensitive sorghum variety can still be harvested, but with reduced yield, if the rest of the season is normal. By contrast a late-sown full-season, maize hybrid may well suffer from late-season drought and fail if the end of the rains is normal.

Importance of Land Preparation

Land preparation and the quality of the seedbed are critical to the early development of the crop. A poor seedbed can have adverse effects on the percentage of seeds that germinate, the availability of moisture to the seedlings, the control of waterlogging, the availability of nutrients, the degree of competition from weeds, and the degree of damage by soilborne pests. All of these factors will affect the plant stand, early crop growth, and **yields.** It should be noted that while the hazards to the crop—and thus loss of potential **yield**—begin as soon as the seeds are put in the ground, the further sowing is from the end of the season, the more opportunities remain for the crop plants and the farmer to compensate for these detrimental affects. For example, millet compensates for low plant density by producing more tillers and heads, maize compensates by producing larger ears (depending on the variety), and a farmer can compensate for excessive early weed competition by doing an extra weeding.

Effects of Sowing Conditions

Soil moisture status, rainfall, and temperature at the time of sowing can also affect the plant stand, the degree of weed competition, and the development of diseases. They can also present some special situations. For example, depending on soil type, the crop can be sown when soil moisture is good, but if the sowing period is followed by an abrupt cessation of rains with high solar radiation and high temperatures, a soil crust can form. If this crust is hard enough, the germinating seedlings will not penetrate the soil surface, even with sufficient soil moisture beneath the crust for normal growth, and it they may die, leading to poor plant stands. On the other hand, farmers may take the risk to sow in completely dry soil ("dry" sowing in some areas is a common practice and also presents risks) when rains are late, get steady rains when the season finally begins, and have excellent plant stands.

Importance of Healthy Vegetative Growth

It is during the **vegetative** stage[4] of growth that the plant is storing nutrients that will be **translocated**[5] to the grain after flowering. In general, the greater the accumulation of biomass in the form of leaves, stems, and roots during this period, the greater is the potential of the crop to produce high **yields.** The most severe **yield**-limiting (and **area-**reducing if severe enough) factors during the vegetative period—short of devastation by animals or locusts—are drought, poor soil fertility, weed competition, low solar radiation, and flooding. Also important are root,

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[4] The growth of cereal crops can be divided into **vegetative** and **reproductive** stages. During vegetative growth, the plant is producing leaf and stem tissue. During reproductive growth, the plant flowers and the seeds develop.

[5] **Translocation** is the movement of dissolved materials throughout the plant.

stem, and foliar insects and diseases, which are nearly always present in one of their many forms, but are only devastating under exceptional (though not to be ignored when present) circumstances.

Practices That Promote High Yields

Many of the factors that limit yields have their effects during the vegetative growth period and can be influenced by farmers' practices. Constraints on high yields are relieved if sufficient labor or herbicides are available for weeding, organic or chemical fertilizers are used to maximize biomass accumulation, animal or motorized traction is available to facilitate drainage, and pesticides are used to control insects and diseases—to say nothing of the use of supplemental irrigation, which is rarely available.

Crops That Tolerate Drought

Millet and sorghum are more drought tolerant than maize and, as a result, are, widely grown in the low-rainfall areas found in most FEWS countries. It is during the vegetative growth period that the different effects of drought and waterlogging on the different crop species are easiest to observe. Sorghum is more drought and waterlogging tolerant than maize, because of its ability to "shut down" during periods of stress and recover when conditions improve. The rolling of leaves of a maize plant is likely to be far more devastating to yields—if not fatal—than the same behavior in sorghum.

Millet is more drought tolerant than maize or sorghum because of its rapid growth, short life cycle and tolerance of high temperatures. The ranges of sorghum, millet and maize production overlap throughout Africa. Maize is found increasingly in traditional sorghum and millet zones, causing a greater frequency of crop failures.

D. From Flowering to Grain Filling

When Drought Can Devastate the Crop

Maize, unlike sorghum, is a cross-pollinating species whose pollen and silks are exposed to the air before fertilization and seed set occur. Drought and associated high temperatures at flowering can severely reduce seed set in maize, leading to poorly filled-out ears and **low yields.** This occurs because temperatures above 35 °C cause pollen death, and the drying of the plant can delay silking—causing asynchronous flowering[6] and the abortion of ovaries. Obviously, knowing the flowering period for a crop in a given region requires local information. However, if the flowering period is known, it will permit a close monitoring of the effect that weather is having on seed set during the relatively short period in the crop's development when the effect can be major.

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[6] **Synchrony** of flowering refers to the silks being receptive to pollen at the time pollen is being produced. Drought can disrupt this synchrony in a maize field.

Flowering Time Is Sensitive for Several Reasons

Other factors that reduce yields at flowering are excessive rainfall and humidity, insects that attack the flower parts (e.g., the sorghum midge or the blister beetle of millet) or newly formed grains (e.g., sorghum head buds), and disease (e.g., smuts, whose spores infect newly formed grains and can destroy the grains of all the major cereals).

Filling the Grains

Grain filling is the period during which the foodstuffs stored in the roots, stems, and, most importantly, leaves are translocated to the newly formed grains. The most critical factors in maximizing translocation are sufficient soil moisture and sunshine to drive the process and a healthy plant foliage, which serves as the source of the materials to be deposited in the grain.

Symptoms of Damage

The yield-reducing effects of insects and diseases become most apparent during this period. Insects that have fed on leaves or stems will reduce the transfer of **assimilates**[7] to the grains or kill the plant. Eggs laid in, on, or near developing grains will develop into larvae that will consume a significant amount of the potential grain production. Diseases of roots and stems can cause reduced translocation or lodging (falling over) of the plants, and foliar disease can kill the leaves—the source of assimilates—before they are translocated to the grains. Smuts, grain molds, and other diseases will degrade the quality of the harvested grains or even destroy them.

When No Rainfall Is Good Rainfall

As the grains reach physiological maturity, which occurs 45 to 65 days after flowering, no more dry matter accumulates and no more moisture is required by the plant. Rain is more likely to have a detrimental effect on the harvest at this point and beyond. The only reason to leave the crop in the field beyond this point is to facilitate the drying down of the grain and other plant parts to be harvested.

E. Harvest and Postharvest

How Bad Is Rain at Harvest

In traditional cropping systems, using traditional varieties, and given normal rainfall patterns, harvest often occurs at the end of the rainy season. However, if left to mature in the field during rainy weather, maize, sorghum, and millet can be severely damaged by grain molds or other fungal diseases. Other hazards that occur during the harvest period are lodging due to waterlogging, insect or disease damage, and high winds. The effect can be to slow the harvest or damage the grains as they lay on the ground. A shortage of labor can be a constraint at harvest time if the harvest is large, if it competes with other activities, or if it is slowed by weather.

[7] **Assimilates** are the foodstuff products of metabolism in leaves, including the products of photosynthesis.

Evaluating the Cereal Harvest

In evaluating the amount of grain that is available for household consumption or sale, it is important to consider the potential postharvest losses[8]. These losses can be highly variable, depending on the crop species, the method and place of drying and storage, the health of the crop as it leaves the field, the time in storage, the type of storage, and handling. The viability of grain kept for sowing will also be affected by the treatment in storage and can have a significant effect on the following year's sowing.

Other factors that affect the quantity and quality of food produced from the harvested grain include the postharvest transformation and associated "milling losses," the shelf life of the transformed product, and the portion of the harvest transformed through animals and the species of animal. In addition, the nutritional value of the cereals will be effected by the other components of the diet. For example, sorghum is more deficient in lysine than maize, so the relative value of the two cereals as a source of nutrition may depend on the availability of lysine from another source.

[8] The USAID Bureau of Food for Peace (FFP) 1988 Manual for Food Needs Assessment includes "losses from insects, rodents, molding, spoilage, and simple mishandling" in postharvest losses. Other nonfood uses include seed, feed, and industrial and processing losses. Milling losses are treated separately in FFP balance sheets.

Section II. What to Look for When Visiting Areas of Agricultural Production

This section is intended to aid in putting into practice the notions on crop production presented in section I. It will provide FFR's with an indication of the type of information that can be collected during interviews with farmers and others who are knowledgeable about the current crop situation and through personal observations made during visits to farms. It provides a checklist of topics designed to supplement the rapid rural appraisal questionnaires that FFR's currently use during the standard FEWS field visits[9] that take place during and just after the cropping season. As with all sections of this paper, there is regional and crop specificity to the information provided. Prior to undertaking the crop monitoring visits discussed here—early in the job assignment—each FFR should attempt to understand the farming system and the factors that go into each years planting decisions (see the box at the end of this section).

This section follows the same chronology as section I so that the reader can refer back to the discussion of the notions that this field visit topics checklist[10] is designed to address. Suggested interviewees include, but should not be limited to, farmers[11], groups of farmers, agricultural extension agents, agricultural cooperative or parastatal managers, NGO and other development/relief personnel, suppliers of agricultural products, and grain traders.

A. The Postsowing Field Visit

Early in the growing season the main objective of visits will be to get a sense of the extent of the planting and determine any problems that may have been encountered that could reduce or boost yields. Keep in mind that we are interested in **crop performance relative to previous years,** so most lines of questioning should be framed to detect indications of increases or decreases in **area** or **yield**.

Extent of Planting and Problems Encountered

Except in conditions of severe drought, the area to be sown will likely be determined within 6 weeks of the **"normal"** sowing date. Six weeks after the **actual** sowing date, the critical time for weeding—one of the major constraints on production—has passed. In addition to asking farmers, How much land do you usually sow? and How much did you sow this year? pursuing the following list of topics will allow a comparison of the current year with a "normal" year.

1. Availability of inputs—Did it restrict area sown?
2. Land preparation—Were the means available to prepare all that was needed?
3. Crops and varieties sown—reasons for choices

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[9] Standard FEWS field visits are a postsowing tour, a preharvest assessment, a postharvest followup, and an off-season vulnerability assessment.

[10] Interview checklists adapted, in part, from *Sociological Analysis in Agricultural Investment Project Design.* FAO Investment Centre Technical Paper 9. FAO 1992.

[11] A suggested approach to interviewing is to first ask general questions relating to the overall farming and cropping system and then to proceed, depending on the responses, to the appropriate specific questions.

4. Rainfall—Did it allow for timely and extensive planting? Was germination percentage high?
5. Were crops planted at the "normal" time? What will be the effect of late sowing?
6. Early growth—Is it vigorous, or was there damage by drought, insects, or diseases?
7. Weeds, weeding, and labor—How bad are weeds? Will they be removed early enough to avoid competition with the crop? Will all the fields be weeded?

B. The Preharvest Visit

Once the critical flowering period (approximately midway between sowing and harvest) has passed and the grains are filling or drying down, most of the potential yield has been determined and most of the yield-influencing operations that farmers can perform have been carried out. Nearly every adult in the rural farming community has a sense of what the outcome will be, and experienced farmers can give highly accurate relative estimates of production. This is also the best time to look at the crops in the field—before they dry down due to natural senescence. Symptoms of all the yield-constraining factors—from poor soil fertility to drought to biotic stresses—are all visible. Issues to investigate at this time include the following:

1. Periods of drought
   -When in the crop cycle did they occur and how serious were their effects
   -Is there stunting, premature dry down, or poorly filled out ears or heads?
2. Cultural practices
   – Key operations and reasons for delays, if any
     -weeding, fertilizer application, hilling of plants, insect control
   – Availability of labor and inputs
3. Major disease, insect or other pest attacks
   -Were there any and what was their effect on yield
4. Seed set
   -Are maize ears or other seed heads missing grains?
5. Plant health
   – Visual symptoms
     -missing plants or week stems
     -reduced height compared to normal
   – -chlorosis[12]; premature drying down of leaves; unusual marks or lesions that indicate diseases; missing parts of leaves or stems--indicating insect attacks; missing or stunted plants from early insect attacks; grains having holes, discoloration, shrivelling or smut spores
   – Farmers' impressions

C. The Postharvest Visit

[12] Chlorosis is the turning of plant tissue from dark green to lighter green to yellow due to the lack of chlorophyll

After the harvest accurate information on the quantity and quality of the harvest is available at the farm level. Marketing, storage, and consumption intentions can be determined and give a very good indication of the ability of vulnerable households to make it through until the next harvest without assistance. Issues to investigate at this time include the following:

1. Grain stocks and market prices
2. Impressions, as quantitative as the informants can be, of the yields and production
3. End use of crops—human consumption, seed, sale, livestock
4. Quality of the harvested product
5. Availability of on-farm storage and intentions
6. Marketing intentions
7. Crop marketing—amount sold, price, where sold, season, buyer, reasons for selling/not selling, reasons for high/low price
8. Food preferences and self sufficiency—degree of food self-sufficiency versus market dependency, seasonality of supply and price of food, what people eat when food supplies run out

The Farming System

To make an objective assessment of the indicators of the area sown, potential yields, and the quality of the season, it is necessary to understand the farming system.[a] For any country, a given crop is likely to be part of more than one cropping system[b] and thus have more than one role in the various farming systems. (For example, maize is an important cash crop when grown in rotation with cotton, on a large scale, using inputs and animal traction in southern Mali. By contrast, further north in Mali it may only be grown in small kitchen gardens, for consumption as fresh maize within the household.) However, once the basic farming is understood, it takes little additional effort to understand the variations. It is possible in most countries to find documentation describing the main cropping systems and the information can also be obtained and made location specific during field visits. The following elements need to be determined in order to understand the farming system and the current year's planting decisions:

1. Overview of the main production systems
   - Relative importance of animals, cash crops, subsistence crops, cereals, legumes, vegetables, others
   - Natural factors affecting the farming systems
   - Soils, climate, rainfall patterns, waterlogging, flooding, drought, etc.
2. Land tenure as it affects farmers' ability or desire to expand the area planted or change crops
3. Cropping patterns and reasons why crops are expanding or contracting or are being replaced—and by what
   - Varieties used and reasons for varietal preference
4. Improved technology
   - Levels of inputs—improved varieties (seeds), chemical fertilizers, pesticides, farm manure
   - Input source, cost, availability, and financing
   - Equipment—animal tractors, carts, plows, seeders, threshers, tractors, grinders, and mills

[a] One definition of a **farming system** given by Harwood in 1980 is "a collection of distinct functional units, such as crop livestock and marketing activities which interact because of the joint use of inputs they receive from the environment.

[b] **Cropping system** refers to the cropping patterns used on a farm and their interaction with farm resources, other farm enterprises, and the technology which determines the makeup.

Section III. Networks for Monitoring Crop Production

FEWS analysts need to rely on secondary sources of information on the progress of the agricultural season. All FFRs have developed a network of sources of information that they contact regularly throughout the growing season. The purpose of this paper is to describe the network of International, and National agricultural scientists and extension workers that can be found throughout Africa. It will also suggest the type of information that these workers can provide that is useful to FFRs in understanding the local farming systems and in monitoring the crop season.

The role of these networks is to develop appropriate farming technologies and to disseminate information on these technologies in order to increase agricultural productivity and the well-being of farmers. Knowledgeable workers in these institutions can provide information on the technology, policy and economic dynamics that are affecting farmer practices and productivity. In addition, as this paper will point out, research and extension agencies monitor the agricultural season as it develops and can provide timely information on harvest prospects.

National Agricultural Extension Networks

National extension services maintain a country-wide network of agents who's role it is to provide information to farmers on the availability and use of inputs and new technologies. At the same time they provide information to central authorities on the needs of the farming community and problems they face. By understanding the priorities of the national extension service FFRs can determine how valuable a resource for information on the cropping season they will be.

Where properly managed, the extension agency can be one of the EW specialists most valuable resources, providing low administrative level production estimates at regular intervals. The extension agents have usually been trained to do crop assessments and can report them in a format that is readily accessible to the FFR. In some cases information available in the capital will be incomplete or anecdotal, but nonetheless, useful. In other cases, the FFR may find particularly well informed and helpful agents, based in the key production areas, and will be able to develop a direct information flow.

National Agricultural Research Systems

These institutions have had up and down histories-- dating from colonial times to the present-- in which they have, at times, been strongly supported by national governments and donors and, at other times, seen their operational budgets shrink. Regardless of their current status, most countries have a network of research sites and researchers and an information base that is a useful resource for FFRs.

Crop Trials Throughout the Country

Agronomic research systems have a hierarchy of research locations; each station having research staff and a farm for field experiments. More central research stations often have large staffs, laboratories and expensive field experiments, while the smallest, associated, research points may be staffed by only one research technician and field laborers. The location of the research stations is designed to coincide with the principal zones of production of the crops being researched and to represent the agroecology of the zone. Research experiments (field trials) are designed to coincide with the normal cropping cycle in the region, and depending on their specific objective--may well use the farmers methods and demonstrate the effects of her/his constraints on crop growth.

Timely Insights on Crop Production

It is useful for the FFR to maintain links with the research network for the following reasons: research trials serve as valuable indicators of crop performance in a region[13]; researchers often get frequent and detailed reports from trial sites and visit the sights during the cropping season; as knowledgeable observers, researchers may be useful in interpreting the effects that poor weather or other yield-limiting factors may have on production; researchers may be able to provide information on local farming systems and the effects of agricultural sector dynamics on production.

Researchers, often in connection with extension services, NGOs and other development agencies, often sow demonstration trials throughout the country so that farmers can observe new technologies. Visits to these sites along the route of a field trip could, again, give an FFR a comparison of the growing season at different locations if the same practices are held constant at the site.

International Agricultural Research Centers

The 16 international agricultural research centers (IARCS)[14], supported by the CGIAR[15], specialize in strategic research in food and agriculture, forestry, agro-forestry, fisheries and food policy. They jointly employ some 1,000 scientists of 60 different nationalities who are working at the centers or in over 200 locations in 40 developing countries.

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[13] One trial may be repeated at 10 different sites and serve as a highly accurate indicator of the relative quality of the season at each site.

[14] The six centers with significant programs in Africa are: CIMMYT, ICRAF, ICRISAT, IITA, ILRI, WARDA.

[15] The CGIAR is jointly sponsored by the World Bank, FAO, UNDP, and the United Nations Environment Programme.

The CGIAR centers have jointly created the largest existing collection of plant genetic resources, accounting for one third of the entire stock of plant genetic material stored in genebanks worldwide.

During the past 23 years, CGIAR centers have trained over 45,000 agricultural scientists, making up virtually an entire generation of national research and policy leaders. National agricultural research systems (NARS) have been strengthened by the CGIAR through management and research policy advice and training. The centers are also active in building and expanding linkages-- such as regional and subregional research networks-- between developing country institutions and other components of the global agricultural research system.

Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT)

CIMMYT, headquartered in Mexico, is engaged in a worldwide research program for sustainable maize and wheat systems, with emphasis on helping the poor while protecting natural resources in developing countries.

<u>CIMMYT's Maize Outreach Programs</u>
The program has also found it advantageous to conduct crop improvement projects at locations outside of Mexico where certain key stresses are prevalent.

The responsibilities of most regional staff are divided between germplasm development or crop management research and assistance to national programs. Some outreach staff, specifically in Zimbabwe and in Cote d'Ivoire- are involved almost full-time in research.

International Institute of Tropical Agriculture (IITA)

The mandate of IITA is to increase the productivity of key food crops and to develop sustainable agricultural systems that can replace bush fallow, or slash-and-burn, cultivation in the humid and subhumid tropics. Crop improvement programs focus on cassava, maize, plantain, cowpea, soybean and yam. Research findings are shared through international cooperation programs, which include training, information and germplasm exchange activities.

International Centre for Research in Agroforestry (ICRAF)

The focus of ICRAF is to mitigate tropical deforestation, land depletion, and rural poverty through improved agroforestry systems.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

The objectives of the center are:

To serve as a world center for the improvement of grain, yield and quality of sorghum, millet, chickpea, pigeonpea, and groundnut and to act as a world repository for the genetic resources of these crops.

To develop improved farming systems that will help to increase and stabilize agricultural production through more effective use of natural and human resources in the seasonally dry semi-arid tropics.

To identify constraints to agricultural development in the semi-arid tropics and evaluate means of alleviating them through technological and institutional changes.

To assist in the development and transfer of technology to the farmer through cooperation with national and regional research programs, and by sponsoring workshops and conferences, operating training programs, and assisting extension activities.

International Livestock Research Institute (ILRI)

Undertakes research to enhance the role of livestock in sustainable agricultural production systems in Africa, Asia and Latin America/Caribbean region. Six program areas address Conservation of Biodiversity, Production Systems Research, Utilization of Tropical Feed Resources, Animal Health Improvement, Livestock Policy Analysis and Strengthening National Agricultural Research Systems.

West African Rice Development Association (WARDA)

WARDA's mandate is to improve rice varieties and production methods among smallholder farm families in the upland/inland swamp continuum, the Sahel, mangrove swamps, inland swamps, upland conditions, and irrigated conditions.