1989/90
CIMMYT World Maize Facts and Trends

Realizing the Potential of Maize in Sub-Saharan Africa

Prepared with the collaboration of IITA

Contents

Foreword

Throughout sub-Saharan Africa, per capita production of maize and other traditional staples has declined in recent years. The worsening prospects for African agriculture are a prime concern of the Consultative Group on International Agricultural Research (CGIAR) and its constituent organizations. Agricultural research appears to have benefited the poor in sub-Saharan Africa less than the poor in other areas, and this perception has led the CGIAR to heightened efforts to resolve food production problems in the region.

CIMMYT and the International Institute of Tropical Agriculture (IITA) are the two CGIAR institutions responsible for work on maize in sub-Saharan Africa. Their activities are oriented to be supportive of the region's national agricultural research programs (for more details on each center's work, see their five-year budget reports). CIMMYT and IITA share the conviction that maize, which throughout most of Africa is largely a subsistence crop produced by smallholders, is the crop with the greatest potential for alleviating the region's chronic food deficits.

The belief in maize's potential in sub-Saharan Africa inspired the feature report in this issue of *World Maize Facts and Trends*. The report reviews major maize production trends, technologies, and consumption patterns; identifies key constraints; and points out possible avenues for improving the productivity of resources devoted to maize production and research. We believe that a clear picture emerges of the highly varied patterns of maize production in sub-Saharan Africa and of the complex constraints that must be overcome.

This report accentuates the need for strong, imaginative cooperation between agricultural researchers and policy makers in delineating and pursuing a collaborative strategy for increasing the productivity of resources committed to maize. Many production constraints require that technological solutions be developed through well-focused research programs. But the complementary role of policy must also be acknowledged. Effective policies—those that address the need for adequate economic incentives for producers, for efficient infrastructure, and for the timely availability of production inputs in sufficient amounts—can foster the adoption of improved technologies. For national leaders to devise such policies, better information will be required; hence the need for the kind of research reported here. Better information will also help focus the allocation of resources to research on key issues.

A final point stressed in the report is relevant beyond sub-Saharan Africa. The constraints discussed here are serious; they demand attention. But researchers and policy makers concerned with the future of food production, whether in sub-Saharan Africa or elsewhere, must not be misled by a sense of urgency into devising short-term solutions for long-term problems. Technological "fixes" that raise agricultural production for a few years at the cost of destroying fragile environments leave a bitter legacy for the future. Agricultural policy and technological innovations must be developed with a clear view to their longer term implications for sustaining agricultural resources and improving productivity.

This issue of *Facts and Trends* concludes that many pressing maize production problems can be overcome. An unequivocal understanding of those problems, based on solid research, is required. Appropriate government policies are crucial to success as well. The pages that follow describe some impressive successes; they also clearly indicate the challenges that remain. We think readers will find this report useful, and we welcome all suggestions and ideas that it might elicit.

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Potential of Maize in Sub-Saharan Africa*

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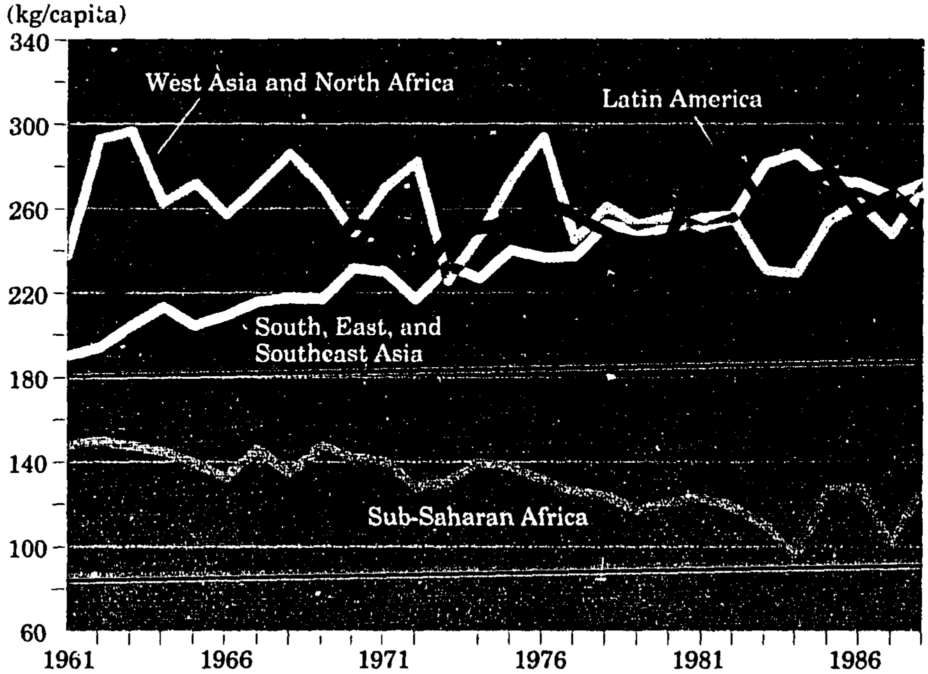
* **Prepared with the collaboration of IITA.**

Introduction

In the wake of the Green Revolution of the 1960s and 1970s, when a sharp surge in wheat and rice production greatly reduced food imports in many developing countries, an end to hunger appeared in sight. More recently, however, some of the greatest beneficiaries of the technological innovations of the 1960s and 1970s—including China, India, Pakistan, and Mexico—have experienced slower rates of growth in cereal production, and there is evidence that historical growth rates may be difficult to sustain (CIMMYT 1989). The realization has slowly been dawning that the Malthusian race between population growth and food production is not yet won, at least not in the developing countries, and that the world's ability to feed itself is more precarious than had previously been thought.

The problem of lagging food production is most evident in sub-Saharan Africa, a region largely unaffected by the technological innovations that so profoundly transformed the world's wheat and rice economies.[1] Unlike Asia, where rice and wheat are the major staple foods, in Africa diets are based primarily on coarse grains (maize, millet, and sorghum) or on roots and tubers (cassava, yams, and sweet potatoes). Many African staple food crops did not benefit directly from the technological advances associated with the Green Revolution, either because improved seed-fertilizer technologies were lacking for the African crops, or, if they were available, because government policies discouraged their adoption by farmers. As a result, food production in Africa has not kept pace with rising population. While population growth averaged 2.9% from 1961-65 to 1984-88 for the region as a whole, growth in cereal crop production averaged only 1.9% during the same period.[2] Thus, per capita cereal production in Africa has actually fallen during the past 25 years, a phenomenon unparalleled elsewhere (Figure 1).

Most African nations have responded to widening food deficits by importing increasing amounts of cereals, primarily wheat and rice. Consumption of imported cereals has been encouraged by economic policies that have made imports cheaper than domestically produced staples, and by demographic changes (such as urbanization and women's entry into the formal labor market) which have increased the demand for convenience foods. For



Source: Calculated from FAO data.

Figure 1. Cereal production per capita by developing country region.

1 Throughout this report, "Sub-Saharan Africa" and "Africa" are used interchangeably to denote all countries in Africa except those in North Africa (Morocco, Algeria, Tunisia, Libya, and Egypt) and the Republic of South Africa.

2 The primary data sources used in preparing this report include the AGROSTAT data base compiled by the Food and Agriculture Organization of the United Nations (FAO), as well as the *World Development Report* series published annually by the World Bank. Some of the data in these sources are questionable, particularly the African data, because official statistics are weak in a number of countries. Empirical results appearing in this report must therefore be interpreted with some degree of caution.

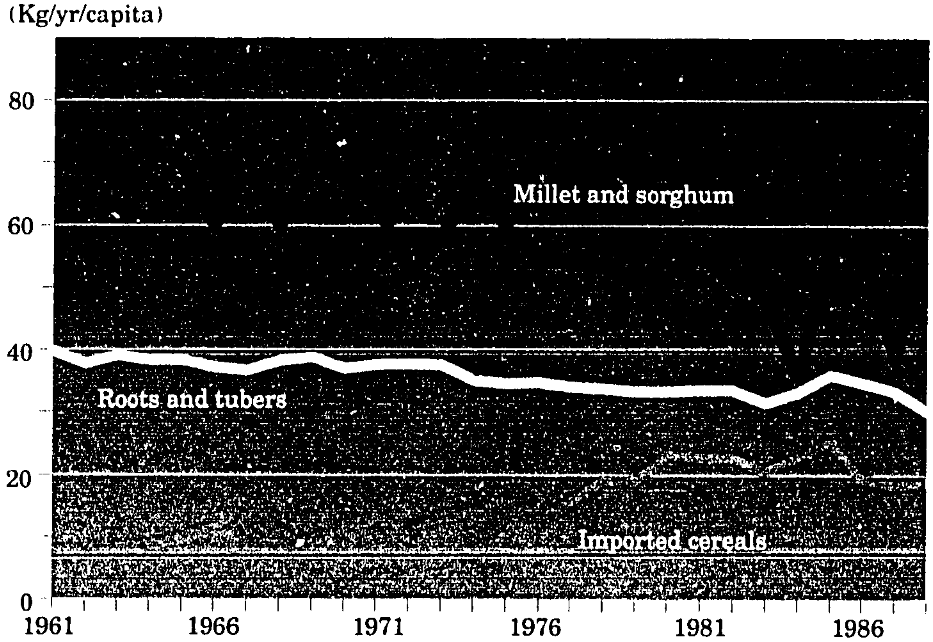
sub-Saharan Africa as a whole, per capita consumption of imported cereals grew at an annual rate of 3.9% from 1961-65 to 1984-88. Meanwhile, per capita consumption of traditional coarse grains, roots, and tubers declined (Figure 2).

These trends are viewed with alarm by many policy makers, because increasing dependence on imported cereals not only uses valuable foreign exchange, but also is perceived as a threat to national food security. A few wealthier countries in Africa can afford commercial imports of cereals, but many others rely heavily on food aid. Despite obvious short-term benefits, food aid is undesirable in the long run whenever it depresses domestic food production incentives. The danger of depending heavily on food aid is heightened by the fact that major donors such as the USA and the European Community recently have pledged to restrain the overproduction of cereal crops, especially wheat, which has made large amounts of food aid possible.

Hardly anyone questions the need to revitalize food production in Africa as a first step toward stimulating economic growth. But how to increase food production is not always obvious, particularly in view of the large and widening gap between the kinds of food that can be produced and the kinds of food that consumers prefer. Demand for wheat and rice is increasing throughout much of the continent, yet climatic and economic factors limit the production of these two crops. At the same time, consumption of millet, sorghum, roots, and tubers is declining, even though these crops are suited to local production conditions.

That leaves maize. Maize production and consumption patterns vary greatly throughout sub-Saharan Africa. In large parts of eastern and southern Africa, maize is the principal staple food, produced and consumed by most farming households. While relatively less important in western and central Africa, maize still provides a major source of calories, especially in parts of Nigeria, Ghana, Benin, and Côte d'Ivoire. But whatever its present importance, maize clearly has enormous potential, because improved technologies offer the possibility of greatly increasing yields and thus production.

This report examines the status of maize in sub-Saharan Africa. To provide a perspective on the performance of maize in Africa, the report begins with a review of global and regional trends in the production of the world's major cereal crops. Subsequent sections present a descriptive overview of the maize economy of Africa, focusing on production systems and technologies, utilization patterns, institutions, and policies. A discussion of critical production constraints is followed by an assessment of future prospects for maize in Africa and priorities for research.



Source: Calculated from FAO data.

Figure 2. Consumption of millet and sorghum, roots and tubers, and imported cereals in sub-Saharan Africa, 1961-88.

Trends in Cereal Production

Cereal Production in the Developing World

Of the major cereal grains grown in developing countries, rice is the most important in terms of quantity produced, followed by wheat, maize, and finally millet and sorghum (Table 1).[3] These rankings have not changed significantly over the past three decades, although the importance of millet and sorghum has diminished as the area planted to these crops has declined.

When historical production data for each of the four major cereals are decomposed into area planted and yield, a better perspective emerges on the sources of production gains in the developing world (Table 2). From 1961-65 to 1984-88, average annual production growth rates were highest for wheat, followed by maize, rice, and finally millet and sorghum. These production growth rates were largely attributable to yield gains, which were particularly strong for wheat (3.7%), maize (2.6%), and rice (2.3%). These data suggest that the conventional wisdom that the Green Revolution affected primarily wheat and rice is not quite correct. Over the past three decades, although yield gains in wheat more than equalled those in the other cereals, yield gains in maize kept pace with those achieved in rice. The only difference was that the gains in maize began later and proceeded more slowly, which made them less conspicuous. However, the gains in maize were sustained over a longer period, so the cumulative effects have been just as substantial. Yield increases in wheat and rice were concentrated in the decade after the mid-1960s, whereas those in maize began only in the early 1970s and continued well into the 1980s.

Maize Production in the Developing World

Maize yields in the developing world have experienced sustained growth during the past 30 years, but these gains have not been distributed uniformly. At least three factors explain the pronounced geographical variability in maize yield gains. First, much of the world's maize is grown in marginal environments characterized by unreliable rainfall or low soil fertility. Second, maize is grown under such a wide range of agroclimatic conditions that improved germplasm or cropping practices cannot always be diffused rapidly or far. (Wheat and rice, on the other hand, frequently are grown in extensive, relatively homogeneous agroclimatic zones—often irrigated—where new technologies can be disseminated more easily.) Third, hybrid maize seed, a principal source of yield gains in industrialized countries, generally requires specialized production and distribution facilities which are lacking in many developing countries.

In view of these considerations, it is not surprising that maize production trends have varied geographically. Progress has been noticeably

Table 1. Area, yield, and production of major cereal crops in developing countries, 1984-88

Crop	Area (million ha)	Yield (t/ha)	Production (million t)
Rice	140	3.20	447
Wheat	100	2.13	212
Maize	80	2.20	176
Millet/sorghum	75	0.92	69

Source: Calculated from FAO data.

Table 2. Growth rates in area, yield, and production of major cereal crops in developing countries, 1961-65 to 1984-88

	Average annual growth rate (%)		
Crop	Area	Yield	Production
Wheat	1.2	3.7	4.9
Maize	1.1	2.6	3.8
Rice	0.8	2.3	3.0
Millet/sorghum	-0.3	1.5	1.2

Source: Calculated from FAO data.

3 By convention, data for millet and sorghum are combined.

slower in countries lacking strong research and extension systems, or lacking well-developed networks for distributing inputs.

The following summary of regional trends in maize production in the developing world shows which areas have benefited most from new technologies and which areas remain relatively unaffected (Table 3, Figures 3 and 4).

Latin America—In 1984-88, 27 million hectares were planted to maize in Latin America; more than three-quarters of this area was in Argentina, Brazil, and Mexico. Use of improved germplasm is quite high in Latin America compared to other regions of the developing world: in 1985/86, 50% of the maize area was sown to hybrids, 10% to improved open-pollinated varieties, and 40% to local varieties (CIMMYT 1987). Combined with a modest expansion in maize area, increased yields have helped fuel an average annual growth rate in total maize production of 3%.

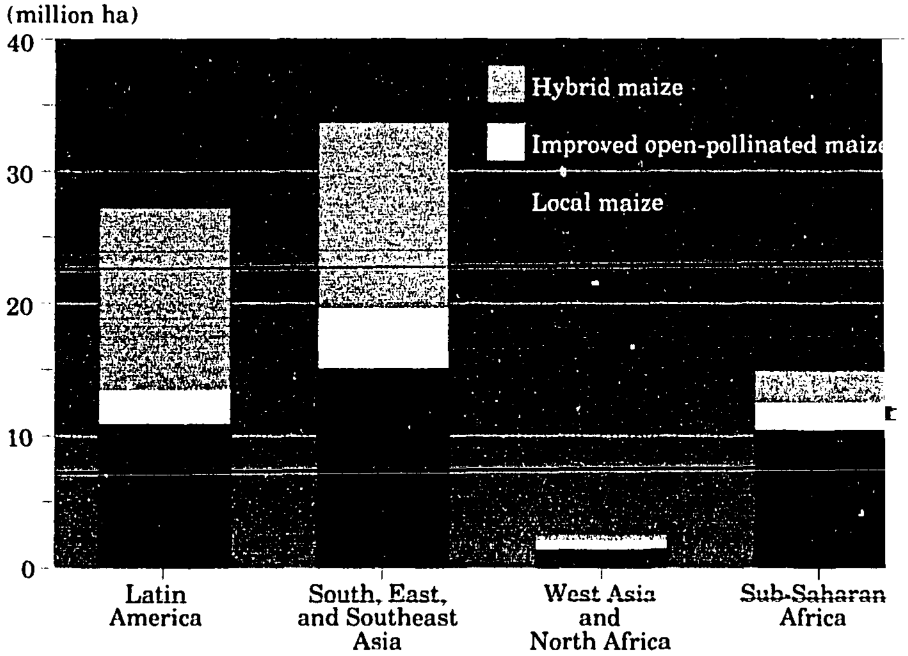
South Asia, East Asia, and Southeast Asia—In 1984-88, 35 million hectares were planted to maize in this region. Area expanded between 1961-65 and 1984-88, resulting in a cumulative increase of nearly 9 million hectares. Use of improved germplasm is high: in 1985/86, 42% of total maize area was planted to hybrids, 14% to improved open-pollinated varieties, and 44% to local varieties (CIMMYT 1987). Yield increases have been impressive, mostly because of large yield gains obtained in China through greater use of nitrogenous fertilizer, improvements in irrigation infrastructure, and the introduction of hybrids. The years from 1973-77 to 1984-88 saw regional maize production accelerate sharply, rising at about 4.2% per year. Average yields currently stand at 2.8 t/ha, among the highest in the developing world.

West Asia and North Africa—Maize area in this region is comparatively small and since the early 1960s has remained around 2.4 million hectares, much of it irrigated. Use of improved germplasm

Table 3. Growth in maize area, yield, and production in developing countries by region, 1961-65 to 1984-88

Region	Average annual percent growth in production due to: Area	Yield	Total average annual percent growth in production
South Asia, East Asia, and Southeast Asia	1.3	3.5	4.8
Latin America	1.0	2.0	3.0
West Asia and North Africa	0.0	2.4	2.4
Sub-Saharan Africa	1.3	0.8	2.2

Source: Calculated from FAO data.



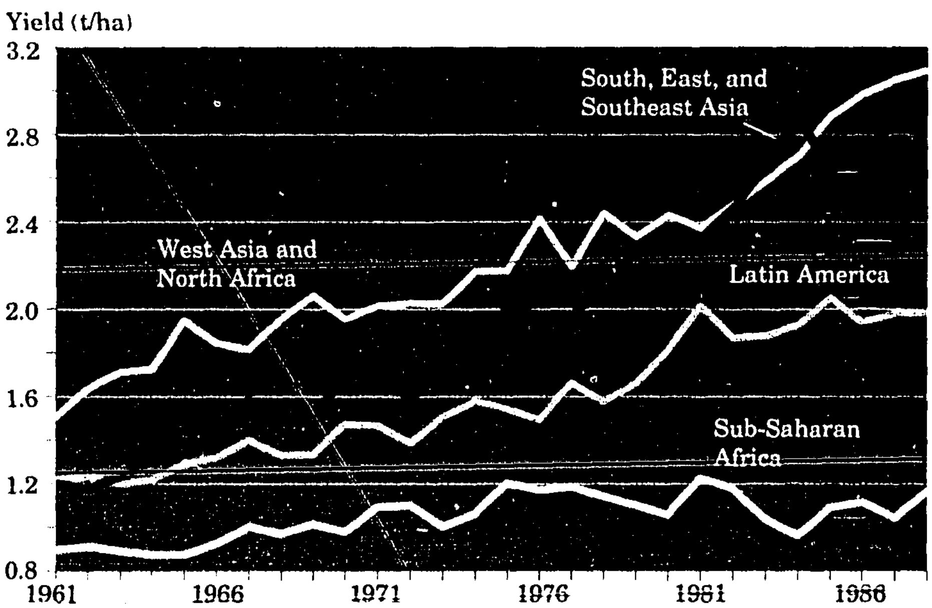
Source: CIMMYT survey data.

Figure 3. Use of maize germplasm by developing country region, 1985-87.

is modest: 15% of the region's total maize area is planted to hybrids, 32% to improved varieties, and 53% to local varieties (CIMMYT 1987). Yields in West Asia and North Africa are high compared to those in the rest of the developing world, mainly because yields are high in Egypt, which accounts for half of the region's production. Since 1961-65, maize yields have grown at an annual rate of about 2.4%. Because area planted to the crop has increased very little, the growth rate of total maize production only slightly exceeded growth in yields during the past two decades.

Sub-Saharan Africa—In 1984-88, nearly 15 million hectares were planted to maize in sub-Saharan Africa. This represented about 19% of developing world maize area but accounted for only 10% of the developing world maize crop. Maize yields in Africa barely exceed 1.2 t/ha, by far the lowest in the world, and since 1961-65 have grown at an average rate of just 0.8% per year from a low initial base. Largely because of the low rate at which yields increased, production grew at a modest rate between 1961-65 and 1984-88. Significantly, production growth rates have declined considerably during the most recent period for which data are available, increasing at a rate of just over 2% per year from 1973-77 to 1984-88.

Several factors contribute to low maize yields in Africa. Much maize in Africa is grown at low density in mixed stands with one or more associated crops, including cassava, sorghum, pumpkin, squash, cowpea, groundnut, yam, and sweet potato. Mixed cropping lowers maize yields, but it helps farmers increase the overall productivity of the resources invested in agriculture and reduces losses if any one crop fails. While mixed cropping is the primary reason for low maize yields, other factors (discussed later in this report) also come into play. For example, land is still relatively abundant in sub-Saharan Africa compared to other regions of the developing world; farmers take advantage of easy access to land by farming extensively rather than intensively, using low levels of purchased inputs, especially fertilizer. Also, many African farmers continue to plant unimproved local varieties. In 1985/86, only 16% of the maize area in Africa was planted with hybrids, virtually all of it in eastern and southern Africa, and an additional 15% of maize area was planted with improved open-pollinated materials (CIMMYT 1987).



Source: Calculated from FAO data.

Figure 4. Evolution of maize yields by developing country region, 1961-88.

Maize Production in Regions of Africa

Maize production varies greatly among the major subregions of Africa (Table 4 and Figure 5). Among sub-Saharan Africa's four major regions (see Annex 2, p. 69, for a list of countries in each region), **southern Africa** is by far the greatest producer and consumer of maize. The region's extensive maize area surpassed 6.4 million hectares in 1984-88 after growing at an average annual rate of 1.4% since 1961-65. Although yields are modest, total production has grown at an average annual rate of 2.8% since 1961-65 and currently stands at just under 8 million tons—96% of the region's maize requirement.

In 1984-88, farmers in **eastern Africa** planted maize on about 4.6 million hectares. Although still low by global standards, eastern African maize yields are the highest in Africa (reflecting cooler growing conditions), averaging 1.6 t/ha. The growth in yields from 1961-65 to 1984-88 was largely the result of adoption of hybrids and increased use of fertilizer. Expanding area and rising yields have helped raise total maize production in eastern Africa at a rate of 2.7% per year since 1961-65. Despite considerable year-to-year variability in production, the region is nearly self-sufficient in maize.

From 1961-65, area planted to maize in **western and central Africa** grew slowly, reaching almost 5 million hectares in 1983-87. Average yields now barely exceed 1 t/ha, after increasing at an average annual rate of 1% since 1961-65. Total production has grown to just under 5 million tons, a level of production that nearly satisfies regional demand.

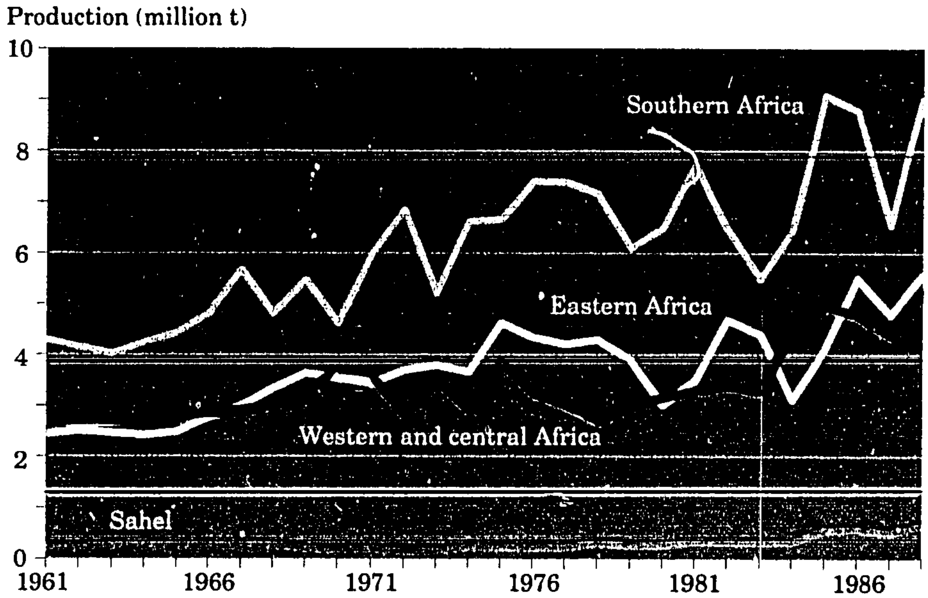
Area planted to maize in **the Sahel** has expanded over the years to reach its current level of approximately 0.5 million hectares. Much of the growth in area occurred when early maturing, input responsive maize varieties moved into zones traditionally occupied by sorghum and millet. Maize production remains modest, currently totalling just above 0.5 million tons. Despite growth in production of 3.2% per year from 1961-65 to 1984-88, self-sufficiency in maize actually declined because of rapid population growth combined with an increase in consumption per capita. During the same period, maize imports rose from a very low base at an average of 8% each year, equivalent to an average annual rate of 5.4% per capita.

Although some of these statistics present a less than optimistic view of African maize production, they do not tell the whole story. They only hint at the diversity and complexity of the maize economy in sub-Saharan Africa, which is shaped by countless biotic and abiotic factors, ranging from cultural preferences and historical influences to agronomic conditions and institutional constraints. The next part of this report gives a more detailed account of the varied and often complex conditions under which maize is produced, used, marketed, and traded.

Table 4. Sources of growth in maize production in Africa, by region, 1961-65 to 1984-88

Region	Average annual percent growth in production due to: Area	Yield	Total average annual percent growth in production
Southern Africa	1.4	1.4	2.8
Eastern Africa	1.1	1.6	2.7
Western and central Africa	1.4	1.0	2.4
Sahel	1.5	1.7	3.2
Total	**1.3**	**1.3**	**2.7**

Source: Calculated from FAO data.



Source: Calculated from FAO data.

Figure 5. Evolution of African maize production by region, 1961-88.

The Maize Economy of Africa

Production Zones

Several major maize production zones can be distinguished in sub-Saharan Africa. The chief characteristics of each zone are described in the following paragraphs.

Eastern and Southern Africa—Maize is the primary staple food of most people in eastern and southern Africa. Presently maize has little competition from other staples, except in a few agroecological zones. CIMMYT has identified eight distinct maize production environments in sub-Saharan Africa, based on agroclimatic factors and grain maturity characteristics (see "Maize Production Zones in Sub-Saharan Africa," p. 8). In eastern and southern Africa, these eight maize environments can be grouped into four basic agroecological zones: lowland tropical (<900 meters above sea level), wet subtropical midaltitude (900-1,500 masl), dry subtropical midaltitude (900-1,500 masl), and highland (>1,500 masl).

Lowland tropical production zones cover about 18% of the maize area in eastern and southern Africa, including the coastal areas of Kenya, Mozambique, Somalia, and Tanzania, as well as parts of Malawi. Rainfall patterns vary; some lowland tropical areas are characterized by a distinct rainy season, whereas in other areas rainfall is distributed bimodally. Soils range from sandy loams to heavier clays. Maize may be monocropped with grain legumes or intercropped with sesame, cassava, cowpea, pigeon peas, tomatoes, or rice. Population growth and the increasing scarcity of land have practically eliminated the long fallows that traditionally were part of the shifting cultivation system, and now continuous cropping with limited rotation is common in most lowland tropical zones.

Subtropical midaltitude zones can be classified as *wet* (>1,000 mm rainfall annually) and *dry* (<1,000 mm rainfall annually). **Wet subtropical zones** cover 49% of the area planted to maize in eastern and southern Africa, including parts of Angola, Burundi, Kenya, Malawi, Mozambique, Rwanda, Swaziland, Tanzania, Uganda, Zambia, and Zimbabwe. Rainfall varies considerably at different altitudes and may be either unimodal or bimodal; in the latter case, two maize crops can be grown. Soils range from deep fertile soils along river bottoms and in lake basins (some of which may be prone to waterlogging) to better drained and more easily worked upland soils. Maize may be monocropped, particularly by commercial producers, but more commonly it is intercropped with beans, cowpeas, groundnuts, pumpkins, or pigeon peas. Since livestock are a significant part of the farming system in this zone, animal manure may be an important source of nutrients for crops.

Dry subtropical zones constitute approximately 16% of the area planted to maize in eastern and southern Africa and are located chiefly in Ethiopia, Kenya, Tanzania, Uganda, and Zimbabwe. Rainfall is unreliable and inadequate. Soils include sandy, sandy loam, alluvial, and volcanic types. Maize is sometimes monocropped, but more frequently it is associated with beans, groundnuts, cassava, cowpeas, or pigeon peas. Planting dates are usually staggered to reduce the risk of losing crops to drought early in the growing season. The unreliability of rainfall discourages farmers in most dry subtropical areas from using inorganic fertilizer, so inadequate soil fertility is a widespread problem.

Approximately 16% of the area planted to maize in eastern and southern Africa is located in **highland zones** in Burundi, Ethiopia, Kenya, Lesotho, Rwanda, Tanzania, and Uganda. Highland zones are characterized by adequate to excessive rainfall, cool temperatures, and long growing seasons. Soils are generally deep and well drained, with a high content of organic matter. Maize is monocropped or intercropped with squash, beans, potatoes, peas, rape seed, or even coffee. Depending on the population density, land may be continuously cropped or fallowed after two to three years of cultivation. The practices that farmers use to maintain soil fertility reflect cropping patterns. For example, inorganic fertilizers are widely used in continuously cultivated areas.

Western and Central Africa—Five major maize production zones can be distinguished in western and central Africa: the humid lowland forest, the semideciduous lowland forest, the derived and southern Guinea savannas, the northern Guinea savanna, and the midaltitude zone (see "Maize Production Zones in Sub-Saharan Africa," p. 8). Cropping patterns are highly diversified and vary from zone to zone (Figure 6).

In the **humid lowland forest**, maize is a minor crop generally planted with the first rains at fertile spots in the field. The main crop is most often cassava, but in some areas, such as southern Cameroon, a groundnut/cassava mixture is grown. Plantain bananas are often interplanted as well, producing a complex system of short-cycle (groundnuts, maize), medium-cycle (cassava), and long-cycle (plantain) crops. Monocropped maize may be grown as an off-season crop in low areas. A chief reason for the relative unimportance of maize in the humid lowland forest is that the crop is

Maize Production Zones in Sub-Saharan Africa

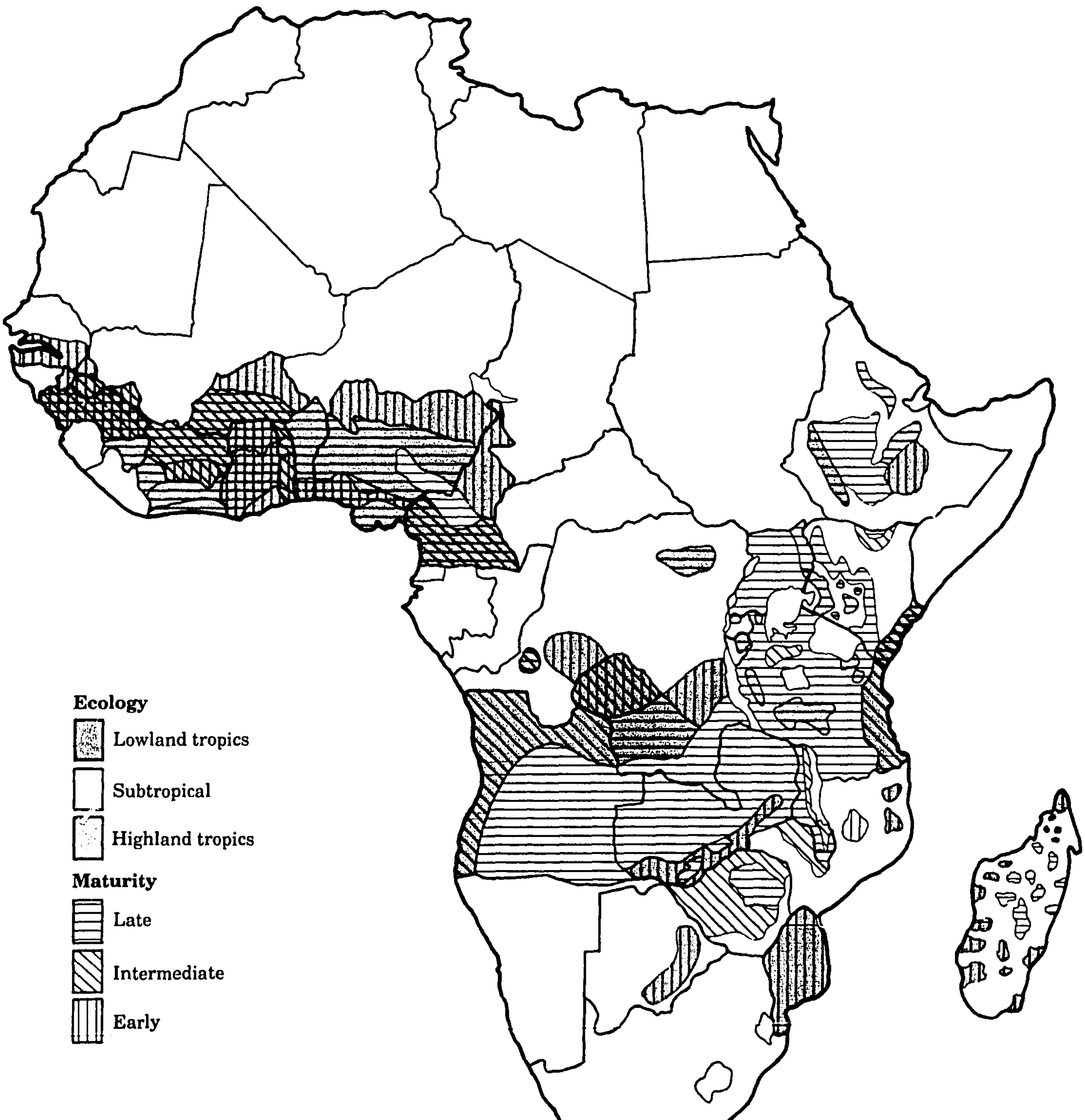
Maize is grown virtually throughout sub-Saharan Africa in a range of agroecological and economic environments. It is the main staple in 18 countries and an important food crop in another 13. Although maize's ability to tolerate diverse growing conditions enhances the crop's importance, this same characteristic complicates the task of classifying production environments and, eventually, of organizing and conducting research. To better determine breeding priorities for the varied environments of sub-Saharan Africa, work on maize zoning has been done by CIMMYT and IITA, among other organizations.

CIMMYT mega-environments--CIMMYT scientists, in cooperation with colleagues in national research programs, have begun work on a mapping system based on so-called *mega-environments* to aid in defining specific breeding objectives. Mega-environments are production zones, not necessarily geographically contiguous, delineated by ecological conditions (temperature, rainfall, soils); crop characteristics (maturity cycle, grain color, grain texture); biotic and abiotic constraints (pests and diseases); and socioeconomic factors (production systems, cropping patterns, consumer preferences). While work on defining mega-environments is still preliminary because reliable microlevel data are scarce, eight mega-environments have tentatively been identified for Africa. Information on these mega-environments, including their approximate size and the incidence within each of biotic and abiotic stresses, appears in Table 1 and Map 1.

Table 1. CIMMYT maize mega-environments for sub-Saharan Africa

Ecological zone	Maturity	Grain color	Grain type	Major insect pests	Major diseases of maize	Estimated area (million ha)
Lowland tropical	Early and extra-early	88% white, 12% yellow	69% flint, 31% dent	Stem borers	Streak virus, southern leaf blight, stalk rot, ear rot	2.03
Lowland tropical	Intermediate	88% white, 12% yellow	58% flint, 42% dent	Stem borers, armyworms, termites	Streak virus, southern leaf blight, ear rot, stalk rot, southern rust	1.60
Lowland tropical	Late and extra-late	92% white, 8% yellow	54% flint, 46% dent	Stem borers	Streak virus, southern rust, northern/southern leaf blight, ear rot, stalk rot	3.60
Subtropical/ mid-altitude	Early and extra-early	100% white, 0% yellow	54% flint, 46% dent	Stem borers, storage pests	Northern leaf blight, streak virus, ear rot	0.13
Subtropical/ mid-altitude	Intermediate	100% white, 0% yellow	0% flint, 100% dent	Stem borers, root/cutworms, storage pests	Streak virus, ear rot, northern leaf blight, common rust	2.30
Subtropical/ mid-altitude	Late and extra-late	92% white, 8% yellow	48% flint, 52% dent	Stem borers, termites, storage pests	Northern leaf blight, common rust, streak virus, ear rot, common rust	4.20
Highland/ transitional	Early and intermediate	83% white, 16% yellow	82% flint, 18% dent	Root/cutworms, storage pests, stem borers	Northern leaf blight, common rust	0.07
Highland/ transitional	Late and extra-late	95% white, 2% yellow	41% flint, 55% dent	Stem borers, storage pests, root/cutworms	Northern leaf blight, common rust, ear rust, streak virus, stalk rot	1.50

Source: CIMMYT Maize Program (preliminary data).

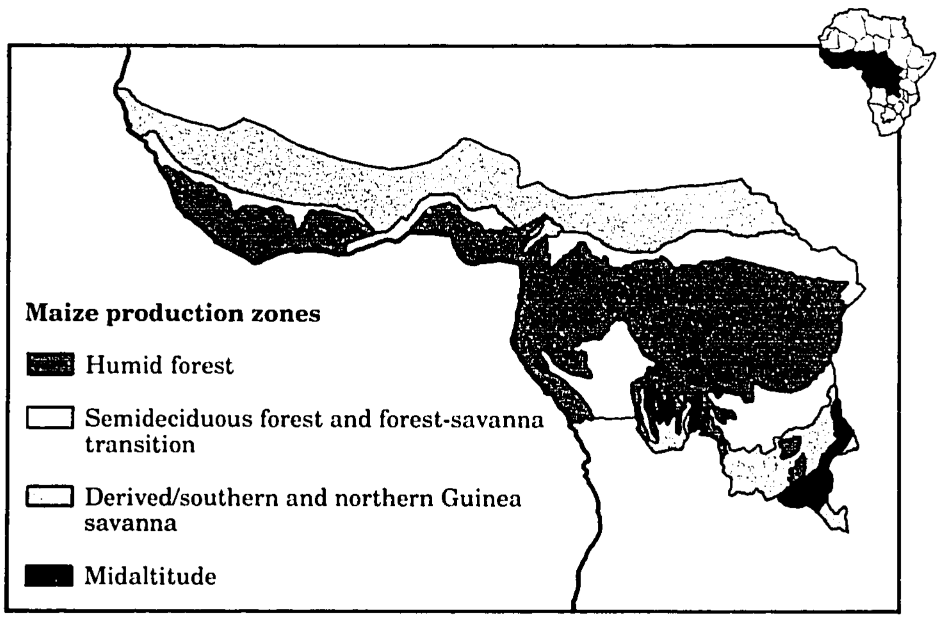


Map 1. CIMMYT maize mega-environments for sub-Saharan Africa.

IITA agroecological zones—Within its mandate area, IITA distinguishes three broad agroecological zones: the forest, the moist (or Guinea) savanna, and the forest/savanna transition zone (IITA 1988). This classification is based primarily on differences in vegetation—strikingly evident as one moves northward from the coast—which in turn reflect differences in soil conditions, climate, and human activity (Map 2).

The three broad agroecological zones are subdivided into five maize production zones (Table 2):

- **Humid forest:** Located in the southern part of the forest zone, the humid forest production zone experiences more than seven humid months (i.e., months in which precipitation exceeds potential evapotranspiration). Rainfall is distributed unimodally or bimodally. Soils are acidic.



Source: Adapted from IITA (1988).

Map 2. Maize production zones, western and central Africa

Table 2. IITA Maize-growing zones for western coastal and central Africa

Zone	Annual rainfall (mm)	Rainfall distribution	Soil types	Climax vegetation	Crops planted with maize	Other major crops
Humid forest (Southern forest)	>1,400	Unimodal	Ultisol, oxisol	Evergreen forest	Cassava, plantain	Oil palm, rubber
Semideciduous forest (Northern forest)	1,250 - 1,400	Bimodal	Alfisol	Semideciduous forest	Cassava	Cocoa, oil palm
Derived and southern Guinea savannas	1,100 - 1,400	Unimodal/ bimodal	Alfisol, ultisol	Woodland savanna	Sorghum, yams	Tobacco, cotton
Northern Guinea savanna	900 - 100	Unimodal	Alfisol	Shrubs, fire-resistant trees	Sorghum, millet, grain legumes	Cotton
Midaltitude (Savanna vegetation)	1,100 - 1,600	Unimodal	Alfisol, ultisol	Mainly woodland savanna	Grain legumes, cocoyam	Coffee

Source: IITA.

- **Semideciduous forest:** Located in the northern part of the forest zone, the semideciduous forest production zone experiences six to seven humid months, with rainfall distributed bimodally in most areas. Two growing seasons are distinguished. Soils are generally not acidic.

- **Derived and southern Guinea savannas:** Encompassing the forest/savanna transition zone and the southern part of the Guinea savanna, this production zone experiences five to six humid months. Vegetation in much of the transition zone is derived savanna, because more forest has been cleared and fallow periods are becoming shorter. Rainfall may be unimodal or bimodal.

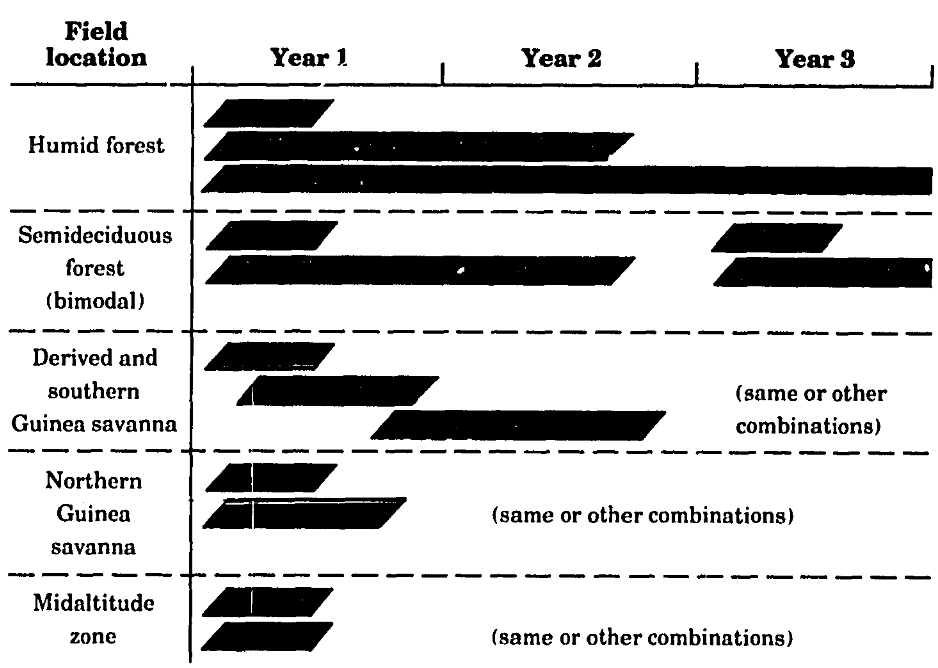
- **Northern Guinea savanna:** The northern Guinea savanna experiences four to five humid months. Insolation during the brief maize-growing season is high, and the long dry season limits the incidence of pests and diseases.

- **Midaltitude zone:** This "zone" actually consists of isolated areas ranging from 1,500 to 1,800 masl. High insolation and cool temperatures make midaltitude areas possible high-potential locations for maize production.

harvested during the rainy season, which leads to storage problems and reduces the attractiveness of maize compared to other food crops. Partly because of the difficulty of storing dried grain, most maize produced in the humid lowland forest is consumed green.

In the **semideciduous lowland forest**, which covers a significant part of the Cocoa Belt of West Africa, maize is second in importance after cassava, with which it is often associated. The two crops are planted mainly during the first rainy season; after maize is harvested, cassava may occupy the land for up to two additional years. Groundnuts are grown with low-density maize in some areas, including southeastern Côte d'Ivoire and central Ghana. Second-season maize is often grown in the semideciduous forest zone, but its success depends on the incidence of certain pests and diseases (e.g., stem borers and maize streak virus), as well as on the amount and distribution of rainfall during the second rainy season.

The **derived and southern Guinea savannas** are the most important maize-growing areas in western and central Africa. Cropping patterns vary widely, but typically maize is planted first in the rotation. After one and a half to two months, sorghum is often relay planted into the maize. This practice takes advantage of the full rainy season, as photoperiod-sensitive sorghum completes its cycle on residual moisture after the rains have stopped. In many areas of the derived and southern Guinea savannas, farmers interplant groundnuts with low-density maize. Sorghum is also relayed into this mixture. In wetter areas, mounds for yams are prepared in the sorghum crop following the harvest of maize or groundnuts; the yams



Note: yams Yam emerges with first rains after maize and sorghum are harvested.

Figure 6. Typical mixed cropping patterns involving maize in major agroecological zones, western and central Africa.

are planted after the rains stop. The early rains are often erratic, and where the rainfall regime is unimodal, staggered maize planting is common.

Maize in the **northern Guinea savanna** is grown in mixed stands along with sorghum, groundnuts, cowpeas, cotton, and yams, although monocropped maize is becoming more prevalent. Traditionally, maize was a minor crop grown near family compounds, where it benefited from regular application of household refuse and organic manure. With the advent of chemical fertilizers, maize has acquired importance as a field crop, particularly in areas where soils are good and fertilizer supply is assured. The minor role played until recently by maize in the northern Guinea savanna is difficult to explain, since temperature and rainfall in this area are favorable for maize (Kassam 1976). However, this situation seems to be changing, as maize has moved rapidly into the zone in recent years (see "Expansion of Maize into the Northern Guinea Savanna," opposite).

Maize is a major crop in the **mid-altitude zone** of central Africa (e.g., parts of Cameroon), where it is generally grown with grain legumes (groundnuts, beans, cowpeas) or tubers (cocoyam). Staggered maize planting is common, so earlier plantings mature during the rainy season and later plantings mature in the dry season. Late-planted maize frequently suffers from maize streak virus and decreased soil fertility caused by nutrient leaching. Soils in this zone are often acidic, and nutrient deficiencies (particularly phosphorus) are common.

Production Technologies

Because of the diversity of agroclimatic conditions, production systems, and producer groups, any summary of maize production technologies in Africa risks oversimplification. Without attempting to be exhaustive, the following discussion provides a general idea of how maize is produced across sub-Saharan Africa.

Eastern and Southern Africa—Three basic groups of producers can be distinguished in this region: 1) small-scale hand-hoe cultivators, 2) medium-scale cultivators who use draft animals, and 3) large-scale commercial farmers whose operations are heavily mechanized.

Small-scale hand-hoe cultivators. Approximately 45% of the total area planted to maize in eastern and southern Africa is cultivated by small-scale farmers (also known as smallholders) who rely primarily on family labor to grow maize on 1-3 ha of land held under traditional tenure arrangements. Cultivation with hand-hoes is often, though not always, associated with heavier soils. Land preparation generally begins before the wet season to take full advantage of the rains but is rarely completed on time, as the dry soil is difficult to work by hand. Maize is usually the first major crop planted, except where high-value cash crops such as cotton or tobacco take precedence. Most maize is sown shortly after the start of the rains, although farmers may make three or more plantings to accommodate limited draft power resources, to reduce the risk of drought losses, and to ensure an extended food supply. Planting method varies. In some areas maize seed is planted in randomly arranged hills, although more commonly it is planted in rows. Seeding rates depend on soil fertility levels, plant spacing, and expected germination rates. Maize may be monocropped or intercropped with other food crops, especially beans, pumpkins, cowpeas, pigeon peas, groundnuts, sweet potatoes, and cassava. Many small-scale farmers choose to plant unimproved local materials because the grain quality of improved materials is unacceptable, or because improved materials offer little yield advantage under the limited level of inputs and management that smallholders can provide. On the other hand, in areas where fertilizer and other inputs are readily available, interest in early maturing varieties has been strong, since these materials give farmers greater flexibility to stagger maize planting. Kenya, Zambia, and Zimbabwe have been particularly successful in delivering improved maize varieties to a large percentage of small-scale farmers, including some hand-hoe cultivators.

Fertilizer use varies greatly among hand-hoe cultivators, depending on soil fertility levels and on the availability of organic or inorganic fertilizers. Many farmers rely on crop rotation strategies to maintain soil fertility, such as intercropping or relay cropping maize with legumes. Animal manure can be a significant source of nutrients in areas where livestock are part of the farming system, although most hand-hoe cultivators have no access to manure. In areas where inorganic fertilizers are available, modest amounts of fertilizer may be used. However, fertilizer is frequently applied late and/or in low doses, so its effect is limited.

Weeds are a serious problem seldom controlled by hand hoeing. One or two weedings are normal, although the first weeding is frequently late, and subsequent weedings are sometimes omitted. As the season progresses, farmers must often compromise between planting more land and weeding maize that has already emerged. The use of herbicides is rare.

(continued on p. 14)

Expansion of Maize into the Northern Guinea Savanna

The high amount of radiation and low night temperatures characteristic of the northern Guinea savanna make this zone the most favorable ecology for maize in western and central Africa, provided adverse soil conditions do not limit production. Yet until the mid-1970s, maize in the northern Guinea savanna was a minor crop valued primarily because, if harvested green, it was the earliest food available after the "hungry period." Families grew just enough maize to sustain themselves until the main cereal crops, sorghum and millet, were harvested.

Today maize production appears to be increasing substantially in this zone. The effect is most striking in Nigeria, where a recent study shows that, in northern Kaduna and southern Katsina States, maize is the most important food crop in over 50% of 15 randomly selected villages and the top cash crop in 60%. The increased importance of maize is also evident, though to a lesser extent, in Bauchi and southeastern Sokoto States. Almost all the maize grown in these areas (with the exception of Sokoto) appears to be improved varieties.

In the past, maize grain was consumed mainly in southern Nigeria. Although maize could be produced in the north, demand there was minimal, and poor transportation made it uneconomical to "export" maize from the north to consumption centers in the south. Beginning in the mid-1970s, however, several factors helped raise maize production in the north. Oil revenues were used to improve roads between the urban south and rural areas of the north, providing northern farmers with better access to southern markets. At the same time, subsidized fertilizer and improved early maturing maize varieties well adapted to the ecology were made available through World Bank-assisted agricultural development programs. Higher yields rather than higher prices made maize more profitable than competing crops; the domestic price of maize relative to competing crops such as millet, sorghum, and groundnuts either remained constant or declined, although it remained high relative to the world price of maize (converted at official exchange rates).

In addition to replacing other crops on land already under cultivation, maize also began to be cultivated on land not previously used for crop production. This expansion in area was made possible by the adoption of animal traction and by increased use of fertilizer, which permitted the elimination of fallow periods in many areas. Also, fertilizer subsidies favored maize because maize is more responsive to fertilizer than the sorghum and millet that it replaced. Eventually the greater availability of maize in the north led to its adoption as a staple food in that area, further reinforcing its attractiveness to small-scale farmers.

The key question now is whether or not expanded maize production is sustainable. Three issues in particular will have to be resolved before maize establishes itself as a crop with long-term prospects in the northern Guinea savanna.

The first issue relates to the future cost and availability of inorganic fertilizer. Maize production in the northern Guinea savanna relies heavily on added nutrients, especially nitrogen. In most countries of western and central Africa, particularly Nigeria, fertilizer has been highly subsidized; when available at official prices, it has generally been cheap, although the quantities available through official distribution channels have often varied. A number of countries in the region are now committed to removing subsidies and privatizing fertilizer distribution, which could lead to improved availability, but at substantially higher prices. The likely impact of these policy changes on future maize production requires further investigation.

A second issue is the future profitability of maize relative to export crops such as cotton and groundnuts. In the past, overvalued exchange rates reduced the profitability of export crops. Now many countries in the region have drastically devalued their currencies, which would be expected to lead to a resurgence in the production of export crops, assuming domestic producer prices reflect international prices. Whether increased production of export crops would occur at the expense of maize remains unclear.

A third issue concerns the impact of continuous maize cultivation on savanna soils. Farmers once relied on a combination of fallowing, manuring, and crop rotation to maintain soil organic matter and preserve soil fertility. As continuous cropping of maize for cash receives greater emphasis, traditional soil conservation practices are being replaced by increased use of fertilizer. It will be important to investigate whether this strategy is sustainable over the long run.

Most smallholders harvest maize when the plants are fully dried. Either the cobs are picked or the entire plant is cut and stooked for later stripping. Much of the harvest is stored on the farm. Most often cobs are kept in cribs, either outdoors or indoors over a fireplace where the smoke helps control insects. In some areas, raised clay or brick outdoor granaries or underground storage pits are used. In other areas, maize may be shelled and stored indoors in sacks, earthen jars, metal bins, or other containers. Given the long dry season in much of eastern and southern Africa, these traditional storage methods perform well, providing good aeration and offering some protection from insects and rodents. The use of insecticides to control storage pests, while rare, is increasing.

Medium-scale cultivators. Medium-scale cultivators who use draft animals (usually oxen) to perform agricultural operations farm approximately 50% of the total area planted to maize in eastern and southern Africa. Most of these farmers rely on family labor and grow maize on 1-10 ha of land held under traditional arrangements. Animal traction is often, though not always, associated with lighter soils. Land preparation generally begins with the onset of the rains, although in some areas farmers plow their land after the previous harvest, before the soil hardens. Most of these farmers use moldboard plows drawn behind oxen. Generally only a single plowing is done, although occasionally it is supplemented by a harrowing before planting.

Planting method varies depending on the area to be planted, soil moisture, and availability of labor. In many dry areas, seed is broadcast directly onto the soil and then plowed in, a method especially suitable for planting a large area rapidly. Dibbling seed behind the plow is another method farmers use to plant quickly while soil moisture conditions are favorable. Seed is dibbled in every other furrow and covered by a return pass of the plow. Hoe planting behind the plow is favored in some places as a means of ensuring uniform stands, although this method requires considerable labor. Finally, in parts of southern Africa, drilling with an ox-drawn planter has become increasingly popular in recent years.

Medium-scale cultivators plant a range of maize materials. As improved varieties become available, farmers have begun to demand germplasm with specific characteristics, especially drought avoidance or drought tolerance, higher yield potential, and responsiveness to fertilizer. As in the case of hand-hoe cultivators, interest in early maturing varieties has been strong because they provide greater flexibility in management. Farmers in some areas also value rapidly maturing varieties because they are ready for consumption earlier in the season.

Both organic and inorganic fertilizers are used to maintain soil fertility. Manure, when available, tends to be of variable quality; since it is bulky and expensive to transport and store, it is applied to only a small percentage of fields in most years. The use of inorganic fertilizers has become more common since many governments improved fertilizer delivery to small- and medium-scale farmers. Inorganic fertilizer, often nitrogen alone, is usually applied basally; less frequently, it may also be applied as an early postemergence dressing and/or as a top dressing during flowering.

Weeds are controlled either by hand hoeing or, less commonly, with ox-drawn cultivators. Row planting facilitates mechanical cultivation, which is generally done several weeks after emergence while the maize plants are still small. Frequently a late ridging is also done to control weeds and reduce lodging. Many farmers who rent oxen to prepare land do not have access to animals later in the season and rely entirely on manual labor for weeding. Chemical herbicides are not commonly used by medium-scale farmers, mainly because herbicides and application equipment are unavailable and farmers do not know how to use them, or because the chemicals damage the intercrop. Harvesting and storage practices resemble those used by small-scale hand-hoe cultivators.

Large-scale commercial farmers. Large-scale commercial producers (known as estate farmers in some countries) farm approximately 5% of the total area planted to maize in eastern and southern Africa. Although the definition of "large-scale farmer" varies from country to country, these farmers usually plant at least 50 ha of maize and often as much as 100 ha or more. Large-scale commercial farmers typically live on their land, which they hold under registered titles. Many also rent land from neighbors who do not farm. Much of the land cultivated by these farmers is located in the high potential zones of Kenya, Malawi, Zambia, and Zimbabwe. Commercial farmers generally produce maize as a cash crop, although in some instances maize is grown to feed workers (e.g., on the tobacco estates of Malawi).

Land is prepared with tractors. An early plowing before the onset of the rains is followed by one, two, and in some cases even three harrowings. Recently this pattern has begun to change. The high cost of operating machinery, and the difficulty of obtaining spare parts in countries lacking the foreign exchange to import them, have led large-scale commercial farmers to experiment with reduced tillage and zero-tillage technologies that do not require such intensive use of machinery.

Commercial farmers plant maize in rows, using either hand-operated seed drills or tractor-drawn mechanical planters. Early planting is associated with higher yields when rainfall is normal, although maize planted early is subject to greater risk in droughty years. If a dry spell occurs just after planting, some farmers can irrigate to help establish the crop. Large-scale farmers tend to grow hybrids, since these materials are well suited to favorable production environments and respond well to high management levels. Hybrid seed is produced by private companies and in some cases by public sector organizations. Certified seed treated with fungicide and sometimes pesticide is usually sold through producers' cooperatives.

Almost all large-scale commercial farmers apply inorganic fertilizers to maize. Application rates vary depending on soil conditions, averaging around 150 kg/ha nitrogen (N), 60 kg/ha phosphorus (P_2O_5), and 30 kg/ha potassium (K_2O) throughout the region (Low and Waddington 1989; Anandajayasekeram and Ransom 1989). In most cases, all of the phosphorus and potassium and about one-third of the nitrogen are applied basally, with the rest of the nitrogen top dressed or side dressed four to six weeks after the crop emerges.

Weeds are controlled by mechanical cultivation and/or with herbicides. Herbicides are applied with tractor-mounted sprayers or by air. Where herbicides are unusually expensive, many farmers reduce costs by combining band spraying on the crop row with tillage between rows.

Large-scale commercial farmers harvest maize with combine harvesters or by hand. Combine harvesters are faster and technically more efficient but expensive to operate, especially in countries where foreign exchange shortages have reduced the availability and raised the cost of imported machinery. When combine harvesters are unavailable or prohibitively expensive, laborers are hired to harvest maize by hand. The ears are picked, deposited directly into tractor-drawn wagons, and transported to storage facilities on the farm. The ears are shelled later using small mechanical shellers, and the grain is bagged for sale.

Western and Central Africa— The associations between specific maize production technologies and broad groups of producers are not as distinct in western and central Africa as they are in eastern and southern Africa. Nor does the scale of maize production vary as much, partly because fewer settlers arrived to foster large-scale commercial farming. However, maize production technologies in western and central Africa are quite diverse, shaped by widely varying agroclimatic and socioeconomic factors. The discussion that follows therefore focuses not on producer groups but on the principal factors that determine which technologies farmers use to grow maize.

Maize production in western and central Africa is for the most part still based on shifting cultivation systems and slash-and-burn methods. In many areas, three or four years of cropping alternate with three or four years of bush fallow, although in some places fallows and/or cropping periods are much longer, depending on population density and soil conditions. Maize is typically intercropped with other food crops, with the predominant combinations varying by production zone.

In much of the humid forest zone, increasing population and shorter fallow periods have compelled farmers to adopt a combination of strategies to prevent soil degradation. The two most important strategies are preserving trees in cropped land and planting a range of crops that provide good ground cover early in the rainy season. If fertilizer is used, it is applied at very low levels.

In the derived and southern Guinea savannas, maize can be grown without chemical fertilizer on good land, especially if the land is located close to household compounds where it can be fertilized with organic refuse. In many areas, farmers allow nomadic cattle herders to keep their animals overnight in a field to improve soil fertility. Whenever farmers have access to inorganic fertilizer, they will apply it to maize rather than to other cereals. Despite these fertility management practices, nutrient deficiencies are common, particularly deficiencies of nitrogen and phosphorus. Low response to major nutrients is often exacerbated by sulfur and zinc deficiencies.

In the northern Guinea savanna, bush fallowing is still widely practiced. However, the fallow cycle seems to be decreasing in some areas and disappearing altogether in others as fertilizer use increases. The major constraint for maize production in this zone is soil infertility, partially brought about by annual burnings that deplete soil organic matter. Maize therefore depends heavily on chemical fertilizer, which is sometimes supplemented by manure and by rotations of maize with legumes. In the absence of chemical fertilizer, the yield potential of maize remains low, around 1 t/ha.

Mechanization increases as one moves northward and inland. In the coastal forest zones, mechanization is practically nonexistent, and virtually all farming operations are performed manually using cutlasses and hoes. Some degree of mechanization has occurred in the savanna zones, where fields are less obstructed by trees and thus more accessible to machinery. In addition, labor constraints appear to be more severe in the savanna because of the much more clearly defined growing seasons, which lead to sharp peaks in the demand for labor (Carr 1989). In the more heavily forested areas of the southern Guinea savanna, where trypanosomiasis (sleeping sickness) is a major problem for cattle, mechanization is still not widespread, but in many parts of the northern Guinea savanna, where the effects of the disease are less severe, animal traction has become well established. Plowing as well as weeding are often done with ox-drawn implements, and animal carts are used for transport. Tractor adoption has occurred in a few areas, often with the help of direct or indirect subsidies, but the use of tractors has yet to prove economically viable throughout much of the region.

The choice of technology to prepare land has important implications for soil fertility, especially on the region's shallower soils. Unless it is carefully managed, heavy machinery can lead to serious soil degradation and can cause dramatic yield declines after only three to four years of continuous cultivation. Ox plowing degrades the soil less than tractor plowing, but in some areas the use of oxen is seriously constrained by trypanosomiasis, as well as by the absence of a tradition of keeping cattle.

Well-developed land markets are practically nonexistent in western and central Africa. Credit markets are generally underdeveloped, although small loans are often available from informal savings associations and thrift societies. These features are consistent with the present relative abundance of land. However, land for agriculture is becoming increasingly scarce, and this scarcity may lead to further development of markets for land and credit.

The prevalence of well-developed labor markets is a bit puzzling, because labor markets tend to be poorly developed where land is relatively abundant (Binswanger and McIntire 1987). The labor markets of western and central Africa are fed by two distinct types of migration: seasonal migration (which occurs when peak labor demands in neighboring production regions do not coincide), and permanent migration (which occurs when the difference in wage rates between one area and another exceeds the costs of moving). Both types of migration are expected to increase as population pressure leads to greater intensification of production in zones of high potential.

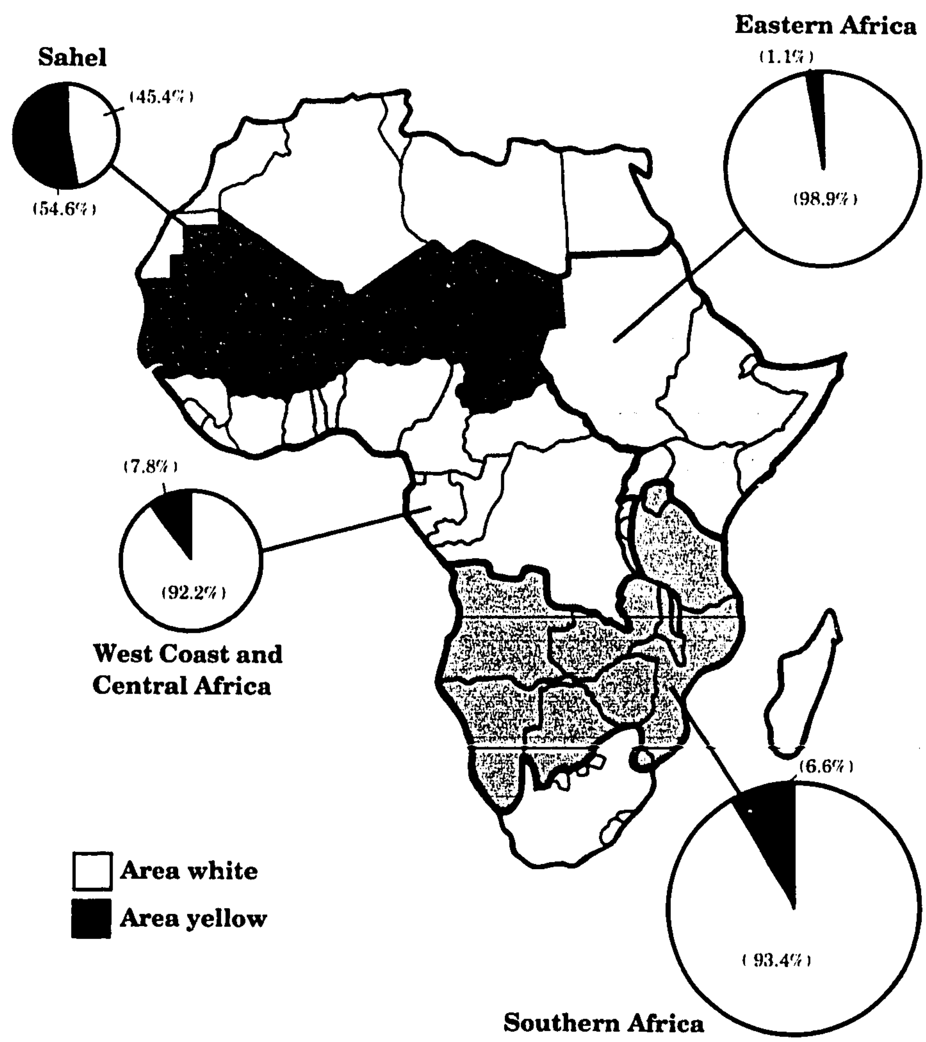


Figure 7. Maize germplasm color by region, sub-Saharan Africa, 1983-87.

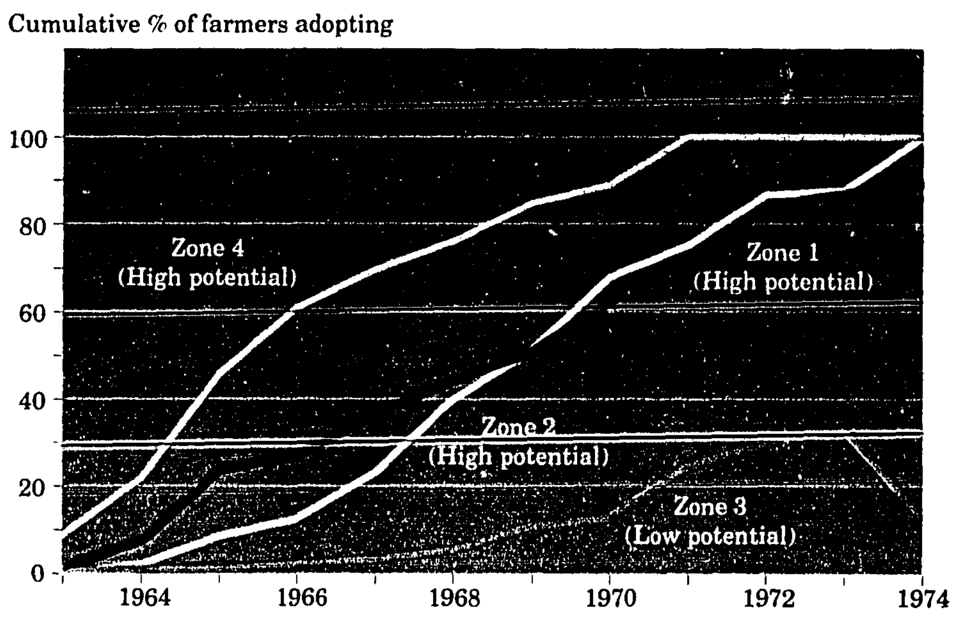
Maize Types Grown in Africa

African farmers plant many different types of maize. White maize predominates throughout the continent, except for the Sahel, where the mix is slightly more balanced between white and yellow materials (Figure 7). Within each color type, the variability in other physical grain characteristics is extensive.

In Africa as elsewhere, use of improved maize germplasm is difficult to estimate precisely, because improved and unimproved materials cannot always be distinguished easily. Since maize is an open-pollinated crop, maize plants in one field often cross with plants in nearby fields if both crops flower at the same time. When improved varieties are introduced in an area where unimproved varieties are grown, mixtures often result, until farmers—and breeders—cannot always tell which varieties are improved and which are not. Alternative methods of determining pedigrees, such as tracing the sources of seed, may provide more valid estimates than simple visual inspection. A further complication in assessing the adoption of improved varieties is that the definition of "improved" material varies. Improved materials are sometimes defined as certified seed purchased during the previous two to three years; in other cases, seed containing mostly improved germplasm is classified as improved. Statistics on adoption of improved materials should be interpreted with these qualifications in mind.

Most African smallholders continue to plant unimproved traditional varieties, while most large-scale commercial farmers grow improved maize.[4] Little empirical research has been done in Africa on economic factors underlying farmers' decisions for and against adopting improved maize varieties. Differences in the rate and degree of adoption can be explained partly in terms of demand (for example, farmers sometimes cannot afford improved seed), but inadequate supplies of improved germplasm usually play a much larger role in slowing the rate and degree of adoption. Of particular importance is the availability of appropriate materials, which depends on local crop improvement programs and/or local seed production capacity.

Maize breeding in eastern and southern Africa for a long time focused primarily on the needs of commercial farmers, who themselves contributed to the germplasm improvement process by selecting materials in their own fields. Today, most national agricultural research programs in the region produce improved germplasm with varietal characteristics desired by both large- and small-scale farmers. The fact that both groups are often interested in the same characteristics is illustrated by the experience of Kenya, where the area under improved hybrid maize increased from 120 ha in 1963 to over 1,000,000 ha in 1988. In high potential zones, small-scale producers as well as estate farmers demonstrated great enthusiasm for the commercial hybrids developed by the national program; smallholders' adoption lagged only in less favorable production environments where hybrids did not perform so well (Figure 8). Hybrids have enjoyed similar success in Zimbabwe and parts of Zambia, demonstrating what can happen when improved germplasm is made available to small-scale farmers (see "Hybrid Maize in Sub-Saharan Africa: Problems and Prospects," p. 21).



Source: Gerhart (1975).

Figure 8. Adoption of hybrid maize in four zones in Kenya.

4 Smallholders in a few countries, including Kenya, Nigeria, Senegal, Zambia, and Zimbabwe, do plant improved maize.

Elsewhere in eastern and southern Africa, improved maize materials have not been adopted so readily, often because they have not met specific requirements of farmers. For example in Malawi, even though farmers expressed a clear preference for flint maize, breeders neglected flint types because they had little access to improved flint maize to use as source material in their breeding work.[5] For years many of the improved maize varieties released by the Malawian breeding program were dent types. Most farmers grew them only in limited quantities for sale, preferring to plant unimproved flint maize for home consumption. The breeding program eventually recognized this problem and now produces improved flint materials as well as dents.

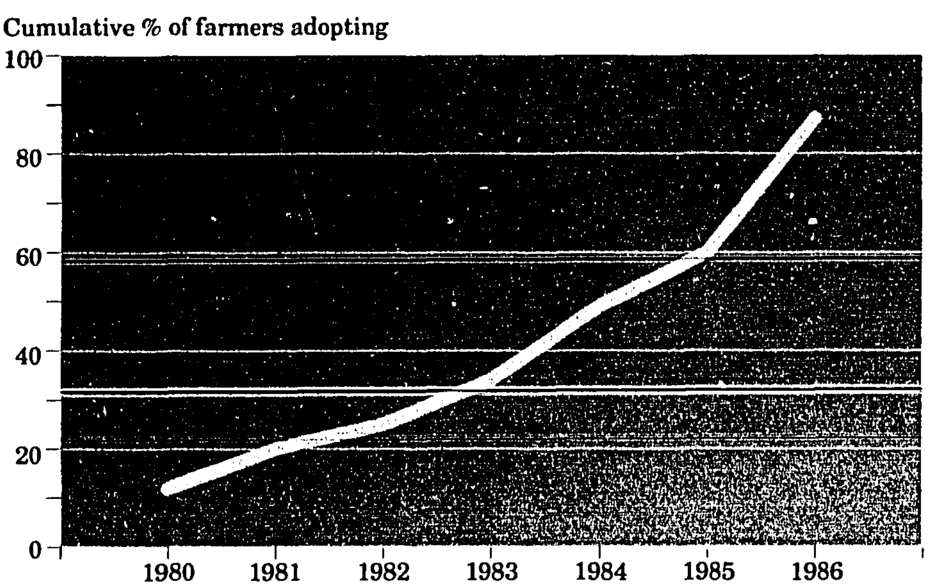
In western and central Africa, adoption of improved maize germplasm also has been uneven. Use of improved materials, chiefly open-pollinated varieties, is extensive in some of the newer maize-growing areas. In Nigeria's northern Guinea savanna (parts of Sokoto State excepted), almost all the maize planted appears to include improved germplasm, mainly TZB and TZPB, varieties that are particularly well adapted to the ecology. Similarly, survey data from the Brong-Ahafo region of Ghana indicate widespread adoption of improved maize materials (Figure 9).

In the more humid savanna and forest zones, improved materials have not been as widely adopted. More than 90% of farmers in Benin continue to plant traditional varieties, in part because improved materials are not always available, but also because traditional varieties suffer less damage in storage and are better suited for local dishes (Yallou et al. 1989). But even in the more humid zones, low adoption rates are far from universal. In southern Nigeria, the spread of seed with predominantly improved germplasm appears high. Inspection of sample cobs from farmers' fields in the semideciduous lowland forest showed that 74% contained improved germplasm (yet only 19% of farmers classified their materials as improved). This high adoption rate may not reflect a conscious decision on the part of farmers; seed storage problems in this area force farmers to purchase new seed every year, and most of it is produced in the north where improved materials predominate (Smith et al., forthcoming).

Hybrid maize has been introduced in a few countries in western and central Africa, but it is unlikely that the area planted to hybrids exceeds 2% in any country. Interestingly, about half the hybrid seed sold in Nigeria is sold in 5-kg packages, implying that smallholders too are adopting hybrids.

Marketing and Price Policy

Government policies pertaining to maize marketing and pricing vary across Africa. Maize markets in eastern and southern Africa are characterized by extensive state participation, whereas most western and central African countries leave marketing and pricing of maize in the hands of the private sector.[6] The sections that follow discuss the sources and implications of this regional variation.



Source: Tripp et al. (1987).

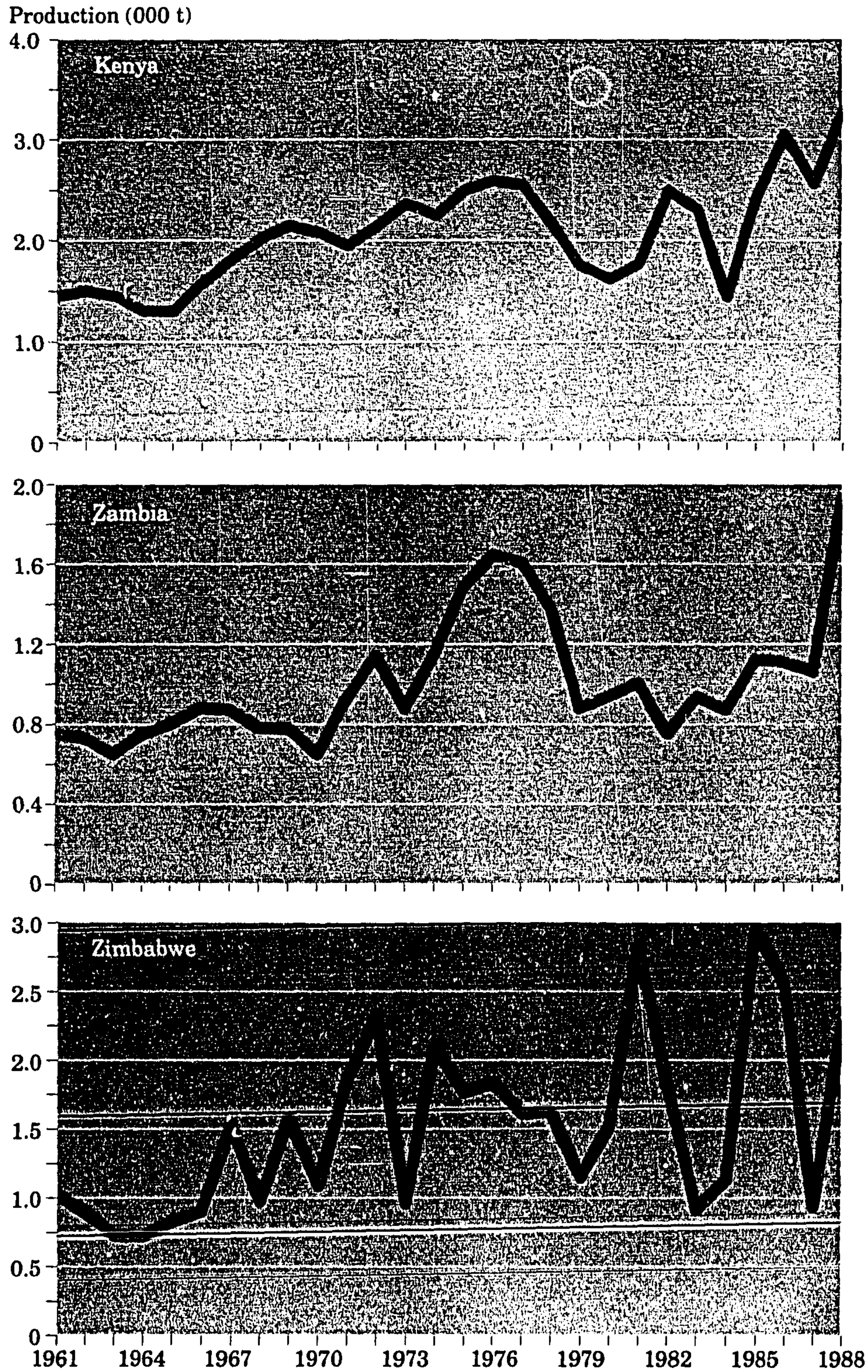
Figure 9. Adoption of improved open-pollinated maize varieties in Ghana, Brong-Ahafo region, 1980-86.

5 The difference between dent and flint maize is discussed on p. 24.

6 Where government-fixed prices exist in western and central Africa, they are generally irrelevant, since market prices in most years differ sharply from official prices.

Eastern and Southern Africa— The economic and political importance attached to maize in eastern and southern Africa is reflected in extensive government involvement in marketing and pricing. Following independence, governments in nearly all of the major maize-producing countries fixed prices from farm gate to final consumer, required that farmers sell maize only to authorized state grain marketing agencies, monopolized maize imports and exports, and strictly regulated the private grain trade. These actions were undertaken for a combination of reasons: to insure an adequate supply of maize to meet national consumption requirements, to reduce variability in supplies and prices, to ensure remunerative prices for producers and affordable prices for consumers, and to minimize unnecessary marketing costs attributable to inefficient private sector intermediaries.

Although the empirical record is far from complete, it is evident that these ambitious—and sometimes contradictory—policy goals have not always been achieved. Production instability continues to plague many maize-producing countries of eastern and southern Africa (Figure 10), because most maize farmers must depend on unreliable and highly variable rainfall. Without improved production technologies to ensure that maize yields remain fairly stable even when rainfall varies from year to year, marketing and price policy alone have proved an ineffective means of breaking the link between rainfall and production. Consequently, most countries in eastern and southern Africa experience alternating periods of over- and undersupply.



Source: Calculated from FAO data.

Figure 10. Variability of maize production in selected countries of eastern and southern Africa, 1961-88.

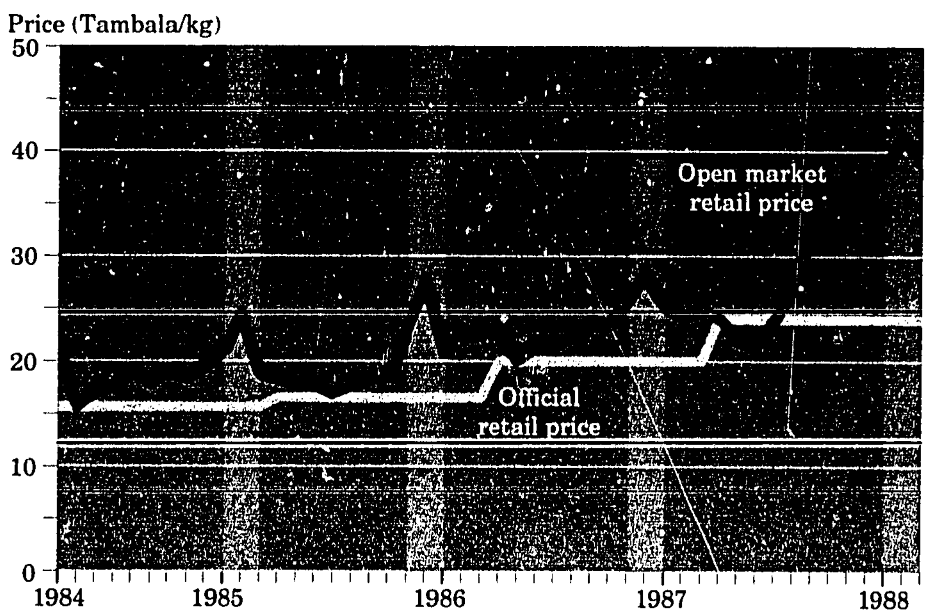
Several governments have attempted to insulate maize markets from the effects of unstable production by introducing policies designed to reduce price fluctuations. Usually these policies set official producer and consumer prices, which for ease of administration remain in place for the entire season (pan-seasonal) and prevail over the whole country (panterritorial). Given the difficulty of eliminating unofficial marketing activities, official prices—if successfully defended—generally only establish limits for the movement of actual market prices (a floor in the case of the producer price, and a ceiling in the case of the consumer price). The ability of the marketing authority to defend the limits established by official prices eventually depends on the resources at its disposal, such as credit to finance purchases from producers, transportation and storage facilities to engage in arbitrage, and stocks to sell to consumers.

Another common strategy that many countries in eastern and southern Africa use to control instability in maize markets is storage policy. Holding sufficient stocks to cover periodic shortages, although costly, allows the government to act as a stabilizing influence in the domestic market; by buying grain in times of surplus and selling grain in times of scarcity, the state theoretically can dampen price and supply fluctuations. The key policy issue, of course, is deciding how much grain to store. The experience of India and other Asian countries suggests that the marketing authority must stockpile enough grain to exert pressure on domestic prices in times of real crisis, not just during periods of "normal" production variability. While it is difficult to judge how much grain will be needed during times of crisis, some analysts have suggested that a number of countries in eastern and southern Africa are maintaining excessively large—and hence unnecessarily costly—reserves (see, for example, Pinckney and Valdes 1988; Buccola and Sukume 1988).

Maize storage policies in eastern and southern Africa have at times succeeded in reducing market instability, but only rarely have price movements been eliminated completely. Despite government efforts, considerable variability in maize prices is the norm in many countries for both producers and consumers. Market prices frequently diverge from official levels, often showing a marked seasonal pattern (Figure 11).

Although the effectiveness of marketing and price policy for maize in eastern and southern Africa is subject to differing interpretations, one fact is beyond dispute: government intervention in maize markets has been expensive. Direct costs—in the form of subsidized prices and marketing services—and indirect costs—in the form of bureaucratic inefficiency and sometimes corruption—have placed a considerable strain on government budgets (for example, see Muir and Takavarasha 1989). Widespread dissatisfaction with the performance of public marketing authorities and the need to cut government expenditures have spurred some governments to encourage a more active role for the private sector in maize marketing. During the 1980s, Ethiopia, Malawi, Tanzania, and Zambia initiated policy reforms designed to free up maize prices and to reduce direct state participation in marketing. So far, these measures are having a positive effect, increasing supply while reducing the strain on government treasuries (Amani et al. 1989; Sipula et al. 1989; Christiansen and Stackhouse 1989).

(continued on p. 22)



Source: Kingsbury (1989).

Figure 11. Seasonal movements in official maize retail prices and open market maize retail prices, Malawi, 1984-88.

Hybrid Maize in Sub-Saharan Africa: Problems and Prospects

Virtually no-one involved in maize research and production would disagree with geneticist Paul Mangelsdorf's (1985) remark that hybrid maize represents the most far-reaching development in applied biology in the latter half of the 20th century. But as true as Mangelsdorf's assertion may be in general, it carries less weight in many developing countries, where the widespread adoption of hybrid maize is frequently aspired to but seldom realized.

Hybrid maize has performed well in developing countries that have temperate production zones, such as Argentina, Chile, and China. These countries contain cool, moist environments with high potential for maize production, and local maize breeders can draw directly on the stock of superior hybrids available in the USA and Europe.

Successful hybrids have been developed for the more favored environments of sub-Saharan Africa, such as the higher altitude areas of eastern and southern Africa. Yield gains of 25% or more over local materials attributable to hybrid germplasm alone have been recorded in numerous on-farm trials. Because the better hybrids deliver reasonably high yields with comparatively low risk, they have been widely adopted in a number of countries.

In hopes of extending these successes, breeders are currently attempting to develop hybrids adapted to the economically and ecologically less favored environments of sub-Saharan Africa. Although relatively little research has been done on hybrid maize in many developing countries, hybrids show less yield advantage when grown under lowland tropical conditions, as in most countries in sub-Saharan Africa. Furthermore, the superiority of hybrid germplasm diminishes when it is grown under low levels of inputs and management: in some marginal environments under subsistence farming conditions, the yield difference between hybrids and open-pollinated varieties becomes narrow or nonexistent (Low and Waddington 1989).

In sub-Saharan Africa, as elsewhere in the developing world, generating superior germplasm is just half the battle. The other half is delivering the materials to resource-poor farmers. Institutional and political barriers frequently limit the production of high quality seed, particularly of hybrids. Poor seed quality often results from inadequate production and marketing facilities, as well as from a lack of adequately trained seed production specialists. These are the predictable consequences of severe budget constraints, especially in the public sector, which tends to be heavily involved in seed production. Poor seed quality can mask the true genetic potential of improved materials and reduce the likelihood that farmers will continue to use them.

Enterprises that produce hybrid maize seed, whether public or private, have a commercial interest in maintaining high standards of seed quality. However, policy barriers often restrict the production and distribution of high-quality seed. Many governments control maize seed prices, with the laudable objective of making seed readily accessible to a greater number of farmers. Unfortunately price controls may reduce incentives for seed producers to provide a high-quality product. In establishing retail seed prices, for example, the governments of some countries have restricted marketing margins earned by seed enterprises to such an extent that they have not been able to meet processing and distribution costs.

To help accelerate the progress of national programs in developing hybrids, CIMMYT and IITA provide information on the combining ability of different materials, improve parents for combining ability, and develop methodologies for producing conventional and nonconventional hybrids. It is important to recognize that the eventual impact of hybrid breeding efforts will depend very much on improvement in local seed production and distribution facilities, which in turn will depend on the general economic climate facing seed producers and farmers. On that front, there are encouraging signs that local seed production capacity is improving in many countries, sometimes with support from multinational seed companies. The experiences of Kenya, Zimbabwe, and Nigeria suggest that the availability of hybrid materials can contribute to the development of a local seed industry and at the same time have an important catalytic effect upon suppliers of fertilizer and other purchased inputs. Significantly, companies that produce and distribute hybrid seed can also handle seed of improved open-pollinated varieties and synthetics, which in many countries will continue to be the most commonly used type of improved germplasm well into the next century.

Western and Central Africa—In contrast to the highly regulated maize markets of eastern and southern Africa, maize markets elsewhere in Africa are rarely subject to government control. Few governments in western and central Africa attempt to participate directly in maize marketing activities, and official maize prices, if even announced, are rarely enforced. The difference in government intervention reflects the fact that maize, which is generally not a primary food in western and central Africa, has relatively less political and economic importance in that region than in eastern and southern Africa.

The interesting question, of course, is whether differing levels of government participation have any appreciable effect on market performance. If proponents of an active role for government are correct, it should be possible to discern problems in the largely unregulated maize markets of western and central Africa. However, market performance is not always easy to evaluate. Numerous studies have sought to determine if maize markets in western and central Africa are economically efficient. In efficient markets, price differences from one location to another approximately equal transportation costs, and price differences from one season to another approximately equal storage costs. Price spreads can also be expected to include normal profits earned by intermediaries on their investment capital, as well as reasonable compensation for risk. If transportation and storage costs, profits, and/or risk premiums are excessive, a market may be inefficient.

There is considerable evidence that marketing margins for maize in western and central Africa are generally compatible with levels that would prevail in competitive markets. The differences between producer prices and retail prices are relatively large because of the high real costs of marketing maize, not because intermediaries wield excessive power that allows them to operate inefficiently or to earn inflated profits. Williams and Oludimu (1986) found that the average 32% marketing margin for shelled maize in Ondo State, Nigeria, was reasonable given the high cost of capital and transport. Margins also were not found to be excessive in northern Nigeria (Hays and McCoy 1977; Delgado 1985) and in Ghana (Southworth et al. 1979).

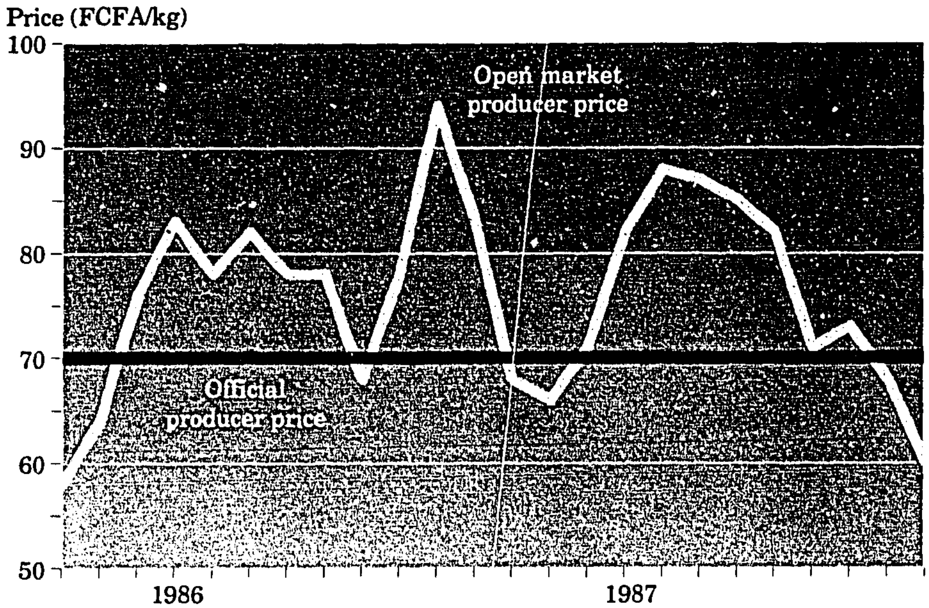
Another determinant of the efficiency of maize markets is spatial integration, which depends on such factors as the regional stability of production on the one hand, and transportation infrastructure, access to information, and availability of credit on the other hand. If regional maize production varies considerably from year to year, flows of marketed grain are likely to change directions unpredictably, and spatial integration is likely to be poor. However, if production is reasonably stable from one region to another, spatial integration can be expected to improve over time as infrastructure improves and as production increases (allowing intermediaries to capture economies of scale in transportation and storage). However, it is often difficult to establish these relationships empirically. Jones (1984) reviewed several studies and concluded that spatial market integration in western Africa frequently is poor because deficiencies in transportation, information, and cash availability may seriously impede efficiency.

Extreme price variability from one season to another is sometimes regarded as a sign of poor market performance. Judged by this criterion, maize markets in western and central Africa appear to perform poorly, since seasonal price differences are particularly large for maize (see Figure 12 for an example from Senegal). Southworth et al. (1979) observed 100% variations in Ghana, and a recent IITA survey done in northern Nigeria found maize prices to be 66% higher during the hungry period (the time just before new crops are harvested, when reserves from previous crops are low or exhausted) than after harvest. However, seasonal price fluctuations of these magnitudes do not necessarily indicate poor market performance, since average storage losses of maize are believed to be as high as 30-40% in many areas.

On the whole, it is difficult to say whether the largely unregulated maize markets in western and central Africa perform better or worse than the highly regulated markets in eastern and southern Africa. Clearly, the economic and political costs of market instability are higher in eastern and southern Africa because maize is so important there. Whereas most consumers in western and central Africa can substitute other staples (millet, sorghum, rice, roots and tubers) for maize when supplies are short, consumers throughout large parts of eastern and southern Africa do not have easy access to substitutes. For this reason, government efforts to stabilize maize supplies and prices in eastern and southern Africa, while costly, are seen as politically necessary.

International Trade

International trade in maize in sub-Saharan Africa occurs mostly between neighboring countries. In normal years, only limited quantities of maize are imported from



Source: Ouedraogo and Ndoye (1988).

Figure 12. Seasonal movements in official maize producer prices and open market maize producer prices, Senegal, 1985-87.

Europe or the Americas, partly because of the type and quality of grain available in global markets: most of the maize traded internationally is yellow, but much of the maize produced and consumed in Africa is white. Worldwide, over 65 million tons of yellow maize are traded annually, compared to less than 3 million tons of white maize, which frequently is unavailable in global markets. Furthermore, most of the maize traded internationally is used for livestock feed, so it is not handled to preserve the high milling quality required in maize destined for human consumption. These factors induce most African countries to import maize from local sources or to import wheat or rice.

For individual regions in Africa, the significance of international trade in maize depends on the local importance of the crop. Trade is much more significant in eastern and southern Africa than in western and central Africa, where the trade in cereal grains involves mainly rice and wheat.[7]

Eastern and Southern Africa—At the start of this century, trade in agricultural commodities was extremely limited in eastern and southern Africa. However, the commercial farming sector's need for guaranteed market outlets eventually led to the development of export markets. Although nonfood crops such as cotton, oilseeds, and tobacco received the most attention, efforts were also made to promote the marketing of food grains. The government of Southern Rhodesia (now Zimbabwe) began encouraging maize exports soon after the turn of the century; by 1914, nearly two-thirds of the maize crop was exported, mostly to Europe for use as livestock feed (Muir-Leresche 1985). The main period of international maize exports from eastern and southern Africa ended in the 1930s, when world maize prices fell sharply. The decline in international export opportunities coincided with colonial authorities' attempts to insulate the region from the uncertainties of global markets.

Eastern and southern African countries continue to sell relatively little maize in world markets, since low global prices, combined with high transport costs, have made exporting unattractive. Trade in maize is seen as a means of disposing of occasional surpluses, rather than as a strategy for ensuring reliable national supplies of the main staple food. However, despite the lack of participation in world markets, some trade continues within the region.

Western and Central Africa—Maize trade is limited in western and central Africa because domestic production in most countries does not fall far short of human needs. However, trade in other cereals is substantial, particularly imports of wheat and rice, whose consumption has long been encouraged by a combination of price policy distortions (e.g., overvalued exchange rates, retail price controls, food subsidies) and structural phenomena (e.g., urbanization, changing employment patterns) (Delgado and Miller 1985). Seeking to increase food self-sufficiency, a number of countries in western and central Africa recently introduced policy reforms designed to promote production of local cereal crops while discouraging imports. In Nigeria between 1978 and 1982, import duties on cereals were raised 50-100%, and quantitative

7 In interpreting official trade statistics, it is important to note that maize trade between neighboring countries is often not recorded, particularly in western and central Africa. Thus, official maize trade data probably understate actual trade flows.

restrictions were placed on cereal imports (maize and rice imports were banned completely in 1985; wheat imports were banned two years later). Ghana, Senegal, and Zaire also tightened restrictions on imported cereals, although less drastically, and relaxed price controls on locally produced staples. While the effects of these actions on maize trade were minimal, the growth of wheat and rice imports decreased, and in some cases maize production increased substantially.

Utilization

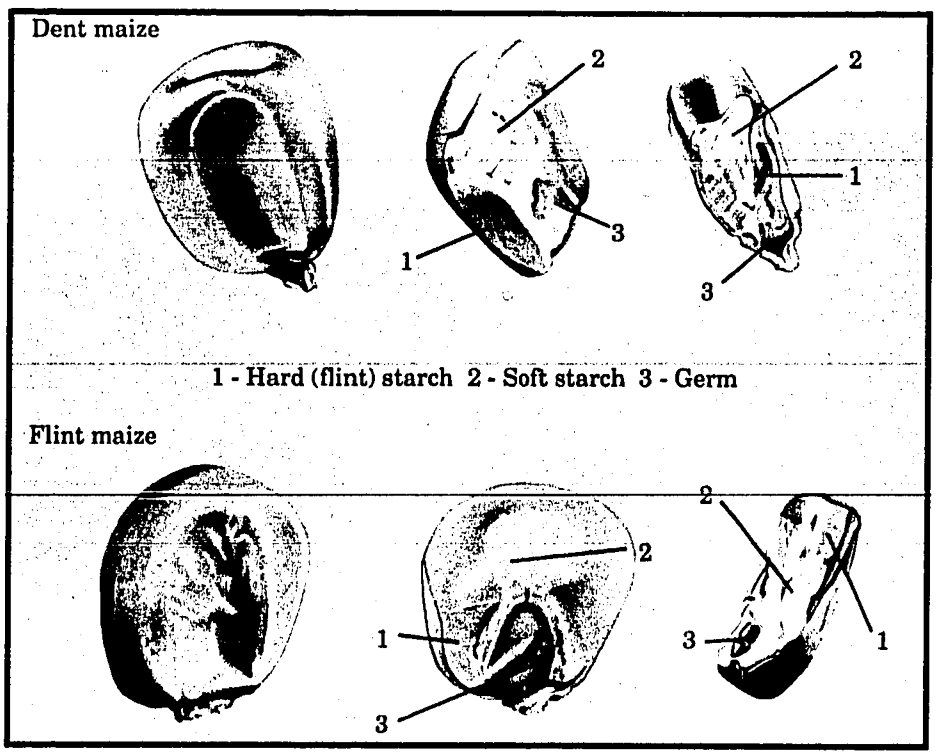
Nearly all maize grown in sub-Saharan Africa is used for human food, with the exception of a small amount fed to livestock (less than 10%). Some maize is consumed green as a snack food, either roasted or boiled. More often, dried maize grain is processed into porridge, soup, fermented paste, or a kind of couscous. In all cases, quality is important, especially texture, color, taste, ease of processing, storage quality, and cooking quality.

Grain texture can be hard (flint) or soft (dent). The denting feature of maize grain comes from the proportion of hard (or vitreous) endosperm in the kernel to soft (or floury) endosperm (Figure 13). In flint materials like popcorn, virtually all of the endosperm is vitreous, and the kernel retains its rounded shape during drying. In dent materials, a core of floury endosperm is embedded in a shell of flinty endosperm; the floury core shrinks during drying, causing the surface of the kernel to collapse inward and giving the grain its characteristic dented appearance. If maize is used as whole grain, flint and dent types differ little in processing efficiency. However, if maize is consumed without the germ, as is common in many parts of Africa, the keeping quality of maize flour improves but processing losses may be greater, especially for dent maize.

In many parts of eastern and southern Africa where maize is the primary staple, rural households show a strong preference for flint maize, which is made into meal. Refined meal is usually produced at home, although partially processed meal may be taken to a village mill for final grinding. In some areas, maize intended for household consumption is taken directly to the village mill to be ground into whole, unrefined meal. However, preferences may be changing. Consumer demand for more refined types of meal in both rural and urban areas has been steadily increasing, probably because more refined meal stores better and cooks faster (FAO 1984).

In western and central Africa, preferences for different grain textures vary depending on how maize is consumed. In areas where grain is wet milled (i.e., milled after being soaked in water for several days), grain texture is less important, and consumers generally prefer flint maize because it stores better. But in areas where grain is milled dry, consumers prefer dent and floury maize types because they are easier to process by traditional milling methods.

Feed use of maize is still modest in Africa compared to the rest of the developing world (Figure 14). At present, only small amounts of maize grain are fed to animals, mostly poultry. However, two developments could change this situation. First, when economic growth resumes in sub-Saharan Africa, rising consumer incomes are



Drawing: Efrén Díaz Chías

Figure 13. Structure of dent and flint maize types.

likely to push up demand for meat and dairy products, increasing the derived demand for livestock feed. Second, if incentives for dairy production improve, intensification of the dairy industry will likely lead to increased demand for maize as feed. While the timing of these two developments remains uncertain, most analysts agree that sooner or later demand for feed maize will increase dramatically in Africa.

In addition to being used for human food and animal feed, maize is also used in processed foods like breakfast cereals and in beer. Industrial uses of maize are expected to grow as more affluent urban consumers shift to foods that are easier and quicker to prepare. Future efforts in maize improvement will therefore need to consider the quality requirements of industrial users such as brewers and food manufacturers.

To a certain extent, increased utilization of maize in sub-Saharan Africa will depend on whether myriad production constraints can be overcome. The next section of this report deals specifically with that issue.

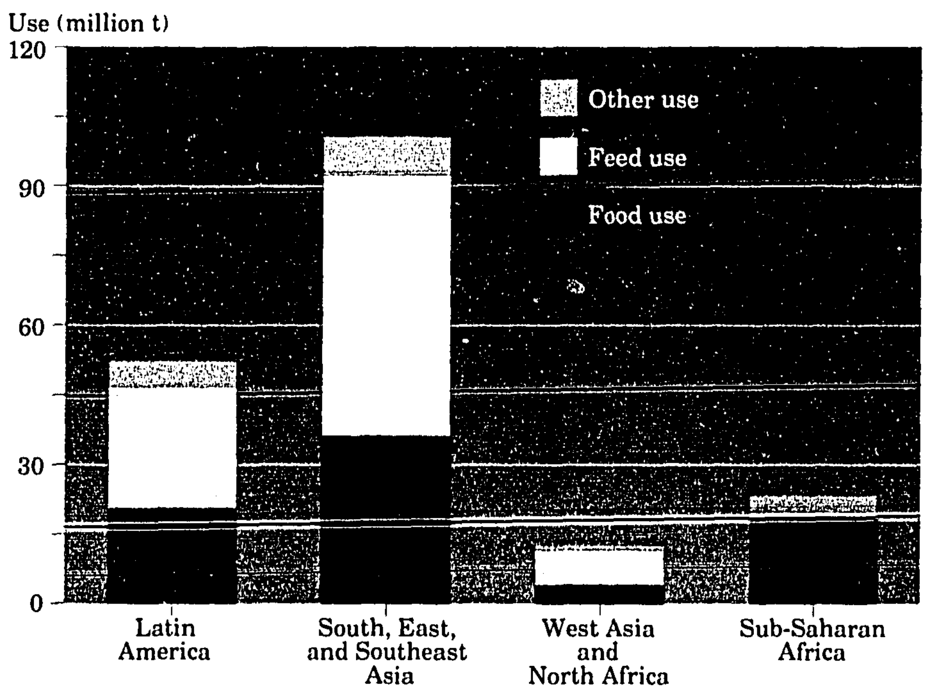
Critical Constraints to Maize Production

Throughout sub-Saharan Africa, farmers' efforts to increase and stabilize maize production are frustrated by numerous constraints, ranging from low soil fertility and unavailability of improved germplasm, to unremunerative prices and uncertain access to markets. However, although the production constraints faced by African farmers are serious, in many instances strategies have been or can be devised to overcome them. Success in some areas, such as parts of eastern and southern Africa where improved maize has been adopted by smallholders, has proven that progress against even a few constraints can go a long way toward realizing the potential of maize for raising food production.

Soil Fertility Problems

Inadequate soil fertility ranks among the most serious constraints on maize production in sub-Saharan Africa. Management practices have depleted soil fertility in many maize-growing areas, especially the reduction in fallowing brought about by increased population pressure. After years of continuous cropping, most African soils are deficient in macronutrients. Nitrogen is usually the most limiting nutrient, followed in importance by phosphorus. Sulfur and zinc deficiencies frequently also depress maize yields, particularly in the savanna.

Providing sufficient nitrogen and other essential nutrients to maize can be difficult. Without long fallow periods, slash-and-burn land preparation cannot support high and sustained maize yields unless nutrients are added regularly. In view of limited availability of organic nutrient sources (animal manure and green manure), many farmers rely on chemical fertilizer as the principal method of maintaining soil fertility. Although it is difficult to estimate how much fertilizer is applied specifically to maize, because data on fertilizer use are usually not disaggregated by crop, total fertilizer use per hectare of arable land for sub-Saharan Africa remains extremely low by global standards, having increased from 3.3 kg of mineral nutrients in 1970 to 8.6 kg in 1986. However,



Source: Calculated from FAO data.

Figure 14. Food, feed, and other uses of maize by developing country region, 1986-88.

these figures conceal tremendous variability between regions, between crops, and between groups of producers. Maize usually receives more fertilizer than other food crops, some of which show a low response to added nutrients (millet, sorghum, cassava), but less than high-value cash crops (cotton, tobacco).

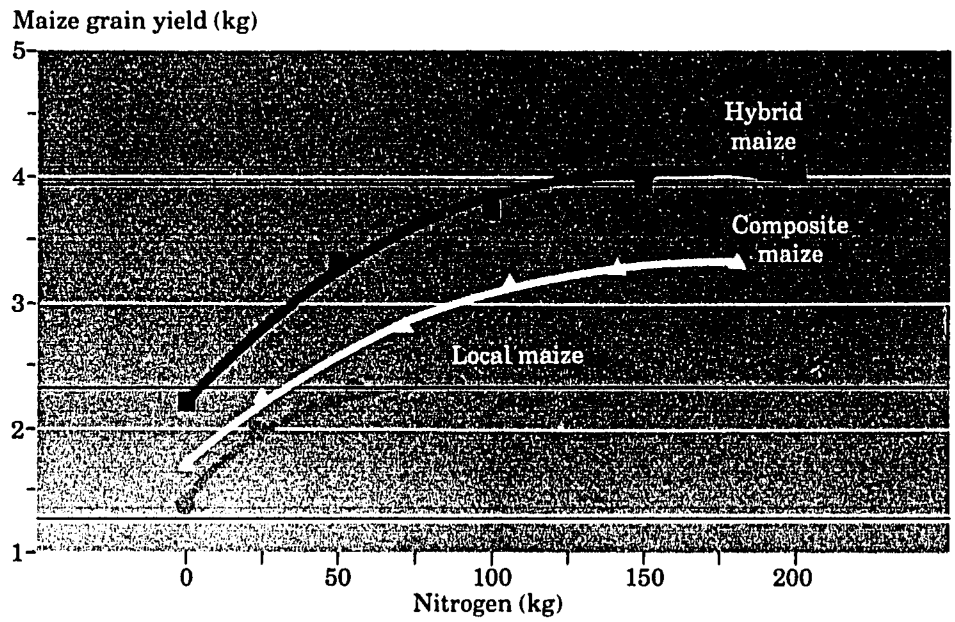
Probably the single biggest obstacle to fertilizer use in Africa is cost. Nutrient-to-maize grain price ratios (which indicate the number of kilograms of maize grain needed to pay for one kilogram of nitrogen) reveal that fertilizer is relatively more expensive in Africa than in either Asia or Latin America, particularly in landlocked countries with no ready access to an ocean port (Table 5). Relatively high prices for fertilizer can be attributed to higher real marketing costs (which are incurred when distributors must move fertilizer over long distances and transportation is poor), as well as to weak and dispersed demand (which prevents distributors from capturing economies of scale). The importance of marketing costs in Africa becomes evident in comparing the cost of nitrogenous fertilizers: the unit cost of nitrogen contained in urea (46% N) is consistently lower than that of nitrogen contained in ammonium sulfate (20.5% N), reflecting the lower cost of transporting the more concentrated formulation.

Relatively high prices do not preclude the use of fertilizer on maize if the yield response is high enough to make fertilizer use profitable. Trial data from sites throughout Africa suggest that modest doses of fertilizer—especially nitrogen—on maize often generate significant yield increases (Figure 15). A study carried out by International Fertilizer Development Center (IFDC) (1985) con-

Table 5. Nitrogen fertilizer price in relation to maize grain price, selected countries, 1988/89

Country	Farm-level nitrogen price (US$/t)	Farm-level maize grain price (US$/t)	Nitrogen-to-maize price ratio
Cameroon	732	100	7.3
Kenya	1,016	112	9.1
Malawi	720	64	11.3
Nigeria	1,333	238	5.6
Zambia	353	125	2.8
Zimbabwe	711	98	7.2
Turkey	476	122	3.9
India	334	163	2.1
Pakistan	321	125	2.6
Philippines	469	164	2.9
Thailand	722	92	7.9
Brazil	796	132	6.0
Chile	599	136	4.4
Mexico	250	158	1.6

Source: CIMMYT survey.



Source: Maize Commodity Research Team, Ministry of Agriculture, Malawi.

Figure 15. Maize yield response to nitrogen fertilizer on estate and smallholder farms, Malawi.

cluded that, at current low levels of nitrogen application, crop response to nitrogen is frequently around 15 kg grain/kg N in forest zones and 33 kg grain/kg N in savanna zones (the difference is partly explained by the higher natural level of nitrogen in forest soils). Data from FAO trials show a crop response of around 10-20 kg grain/kg N at rates of 20 kg N/ha, falling to 6-14 kg grain/kg N at rates of 40 kg N/ha (McIntire 1986).

Whether or not these crop responses are sufficient to justify the increased cost of purchasing and applying fertilizer depends on a number of factors, including the price of fertilizer, the price of maize grain, and the cost of additional labor required. Partial budget analyses done in several countries indicate that fertilizer use on maize is often profitable at prevailing market prices. On the other hand, researchers, extension agents, and especially policy makers should not be lulled into believing that it is always profitable to use fertilizer on maize. On-farm trial data from a number of sites suggest that, when other factors that limit yields are present (e.g., lack of water, inadequate weed control, or deficiencies of complementary nutrients) maize may respond only modestly to increased applications of fertilizer. If such constraints are present, increased fertilizer use on maize may be unprofitable, and farmers would be making an economically rational decision in choosing not to apply additional fertilizer.

Subsidies often encourage inefficiently high levels of fertilizer use. In a series of on-farm trials at 222 sites in different agroclimatic zones throughout Ghana, two levels of fertilizer application were compared to the practice of using no fertilizer (Table 6). The marginal rate of return to the resources invested in fertilizer is positive for both fertilizer treatments, if 1987 prices for inputs and maize grain are used in the calculations. However, 1987 market prices in Ghana included a large fertilizer subsidy, which reduced the nutrient-to-maize grain price ratio to approximately 2:1. If the subsidy had not been present and fertilizer had been sold to farmers at a price reflecting its true import cost, the nutrient-to-maize grain price ratio would have risen to approximately 4:1. Using this higher ratio, the marginal rate of return to the resources invested in fertilizer would have been positive for the lower fertilizer level (Treatment 2), but negative for the higher one (Treatment 3). These data support the view that fertilizer use on maize in many parts of Africa can be justified economically only at relatively modest levels (Carr 1989).

Table 6. Economic profitability of fertilizer use on maize in Ghana under two levels of fertilizer prices

	Change in practice from:	
Fertilizer price level	**Treatment 1[a] to treatment 2[b]**	**Treatment 2 to treatment 3[c]**
Nitrogen-to-maize grain price ratio = 2:1		
Marginal costs (cedis/ha)	8,866	7,222
Marginal benefits (cedis/ha)	32,934	11,778
Marginal rate of return to additional investment (%)	271	63
Nitrogen-to-maize grain price ratio = 4:1		
Marginal costs (cedis/ha)	14,796	13,740
Marginal benefits (cedis/ha)	27,004	5,260
Marginal rate of return to additional investment (%)	83	-62

Source: Ghana Grains Development Project.
a Treatment 1 = no fertilizer; yield = 1.6 t/ha maize.
b Treatment 2 = 50 kg N/ha, 25 kg P_2O_5/ha; yield = 2.7 t/ha maize.
c Treatment 3 = 100 kg N/ha, 50 kg P_2O_5/ha; yield = 3.2 t/ha maize.

In addition to high cost, a second obstacle to increased fertilizer use in Africa is limited availability. Many farmers cannot obtain fertilizer when they need it, or in the formulations they desire. Many factors contribute to fertilizer supply problems. Planning and administering a national fertilizer program requires skills that are not always available in the government agencies that oversee input supply, and the private sector also may experience problems in distributing fertilizer (Shepherd 1989). Furthermore, fertilizer imports have to be financed with foreign exchange, which is often in short supply. These problems are compounded by lack of facilities for importing, storing, transporting, and distributing a bulky input whose chemical composition can be affected by exposure to the elements. Consequently, even when fertilizer is available to farmers on time, its potency often has been lowered by improper handling.

Of course, applying chemical fertilizer is only one strategy for maintaining soil fertility. Other technologies being investigated include crop rotation, crop residue management, use of live mulches, planting of cover crops, and agroforestry techniques such as alley cropping, in which woody leguminous species are grown in hedgerows with food crops in between. Research on experiment stations has demonstrated the effectiveness of these technologies in maintaining soil fertility, but further on-farm testing is required to determine whether or not they are economically viable from the farmer's point of view.

In some areas, large-scale commercial farmers have begun to experiment with zero-tillage techniques (which use herbicides to replace cultivation) to manage soil fertility. Although early results are promising, it is important to keep in mind that herbicides are complex to manage; thus, zero-tillage can succeed only where the supply of inputs is dependable, site-specific adaptive research is possible, and support from extension is available (Carr 1989).

Generally speaking, the adoption of improved soil management technologies has been limited in Africa. The abundance of arable land has meant that pressure to adopt intensifying technologies—including soil management practices and chemical fertilizers—has not been as great in Africa as in other parts of the world. However, the situation is changing rapidly. As population has grown and land use has intensified, soil fertility levels have declined drastically in many maize-growing areas, to the point where inadequate soil fertility now poses the single most important constraint to maize production.

The importance of pressing ahead with research on soil management technologies that offer an alternative to continuous use of chemical fertilizer is highlighted by recent evidence showing that fertilizer alone may be insufficient in the long run. Results of long-term IITA fertilizer trials in alfisols (a major soil type for maize production) indicate that continuous application of nitrogenous fertilizer can lead to declines in soil pH, organic matter, and nutrient status. Adding large quantities of organic material can alleviate some of these problems (Kang and Balasubramanian 1990). Clearly, an integrated approach to soil fertility management that combines biological nutrient sources with inorganic fertilizer will be needed to maintain sustainable production.

Limited Use of Improved Germplasm

Improved maize germplasm has not yet been developed for all African agroecologies, but improved materials are available for most of the major lowland and subtropical production environments. The superiority of these materials has been confirmed under a variety of production conditions. In experiment station trials involving high levels of management, improved materials yield substantially better than local checks (CIMMYT 1989). Under farmers' conditions, improved materials usually retain some yield advantage, even in marginal zones. For example, Rohrbach (1988) reports that in Zimbabwe the hybrid R200 yields 30% more than local varieties without fertilizer, and that the yield advantage is even greater under drought stress. Similarly, a decade of on-farm experimentation by the Ghana Grains Development Project affirms that certain improved maize varieties regularly yield better under varied agroclimatic conditions and management levels.

Given the superior performance of many improved materials, it is reasonable to assume that African farmers would grow them if they could. As noted earlier, seed of improved varieties simply may not be available to farmers. Most maize seed in Africa is produced and distributed by the public sector; private sector involvement is rare, because private seed companies make most of their money on hybrids, and use of hybrids is still minimal in most areas. A high degree of specialization and considerable expertise are required to produce maize seed (CIMMYT 1987). Constrained by insufficient resources and inadequately trained personnel, public sector seed companies in Africa have not always demonstrated the ability to produce and distribute adequate supplies of high quality maize seed.

This idea—that low use of improved germplasm often can be attributed to poor availability of seed—is reinforced by the experiences of Kenya and Zimbabwe. In each of these countries, strong demand from the commercial farming sector for improved maize materials led to the emergence of an efficient private seed industry. After building a solid base of sales among commercial farmers, this industry extended its distribution network into rural areas, making improved materials readily available to smallholders lacking the means to travel long distances to procure seed. Widespread adoption of improved germplasm followed. Significantly, the key to success in Kenya and Zimbabwe lay not only in the development of appropriate germplasm, but equally importantly, in the emergence of an effective seed production and distribution system capable of delivering its product to smallholders.

In certain cases the reason for low use of improved germplasm is more fundamental than poor seed production and distribution: suitable germplasm has not been fully developed, let alone released to farmers. The yield advantage offered by improved materials remains slight in some areas. Dahniya et al. (1986) found that, in on-farm trials conducted on a range of sites in Sierra Leone, the local check performed better than two improved materials when no fertilizer was applied. In such cases, farmers are making a rational decision in electing not to adopt improved materials, and additional breeding work is necessary.

Drought

Approximately 40% of the maize area in sub-Saharan Africa experiences occasional drought (defined as causing average yield losses of 10-25%), whereas 25% experiences frequent drought (causing average yield losses of 25-50%). In eastern Africa, southern Africa, and the Sahelian zone of western Africa, almost all ecologies in which maize is produced are characterized by unpredictable dry periods of one to three weeks or more.

Maize farmers in Africa have developed many strategies to cope with drought, including selecting drought resistant or drought tolerant germplasm, using water harvesting techniques to take maximum advantage of available moisture, staggering maize planting dates, and diversifying cropping systems to reduce the risk of crop failure. Strategies used by subsistence farmers often are designed to enhance yield stability (to ensure at least enough production to meet minimum household needs), even if that means average yields will be lower.

Current work on drought problems in maize includes both germplasm improvement and crop management research. IITA, CIMMYT, and several national breeding programs are developing maize populations with improved drought resistance. IITA and a number of national research systems in the Sahelian countries collaborate on drought work under an initiative funded by the Semi-Arid Food Grain Research and Development (SAFGRAD) project. Scientists in the SAFGRAD project have followed two breeding strategies: they have sought to improve drought tolerance to mitigate the effects of the dry spells that occur during the growing season, and they have also tried to reduce the time to maturity so that maize escapes periods of unreliable rainfall at the beginning and end of the rainy season.

At CIMMYT, four broadly adapted elite populations have been chosen for improvement as drought tolerant materials; the objective is to provide national programs with late white, late yellow, early white, and early yellow maize populations to use as sources of drought resistance. In addition, cultivars that do well despite droughty conditions have been combined to form the Drought Tolerant Population (DTP). Recurrent selection within these populations is based on morphological and physiological traits that have been linked to drought tolerance, including delayed leaf senescence and reduced anthesis-silking interval, in addition to high grain yields under moisture stress (Edmeades et al. 1988).

Crop management research for droughty environments has focused on soil management techniques such as mulching and ridging, which are designed to increase and preserve soil moisture levels, as well as on techniques designed to achieve optimal plant population densities and spatial arrangements for maize grown in dryland conditions. Evidence from experiment station trials as well as farmers' fields indicates that tied ridging is particularly effective for preserving moisture and raising grain yields, except in sandy soils (Figure 16). However, the economic feasibility of tied ridging must be evaluated case by case, because the yield increase does not always justify the significant labor input required to construct tied ridges.

Weeds

Most weed control in Africa is performed manually or using animal-drawn cultivators. The frequency and timing of weeding vary, depending on the severity of weeds and the availability of labor. One or two weedings are common in most areas, although they are often delayed because of seasonal labor constraints. Weeding maize during a critical period 10-30 days after crop emergence greatly enhances grain production; uncontrolled weed growth during this period can reduce maize yields by 40-60% (Akobundu 1987). Weed competition is particularly problematic in arid and semiarid zones, since moisture lost to weeds translates directly into yield losses in the maize crop.

Although agronomic data from experiment station trials demonstrate a clear link between timely weeding and enhanced maize yields, economic data from on-farm trials do not always confirm the profitability of "improved" weeding practices. On-farm weed control experiments are notoriously difficult to manage, since weed growth varies across sites and between seasons, and defining a standard baseline "farmer practice" is not easy. Economic analysis of trial data is complicated by the difficulty of estimating the opportunity cost of labor (often family labor), which may change throughout the season. Many African farmers in fact adjust their weeding practices according to the level of weed infestation and labor availability, which suggests they appreciate the necessity of weeding and allocate labor to weeding when it pays to do so.

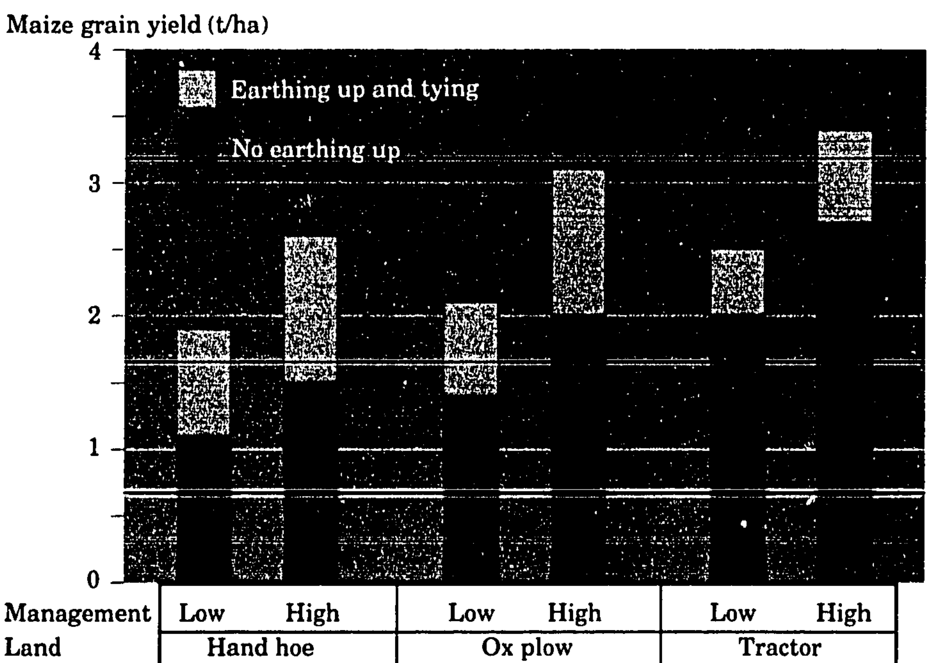
Where weeding competes for labor with other income-generating activities, herbicides have often been investigated as an alternative form of weed control. As with many other improved technologies, returns to herbicide use are highly sensitive to site-specific factors. Work done in Zambia suggests that adoption of chemical weed control in maize is more likely to be profitable for large-scale farmers with access to tractors than for smallholders (Vernon and Parker 1983).

Striga, also known as witchweed, is an indigenous parasitic weed that attacks the traditional crops of the African savanna, including maize, sorghum, pearl millet, groundnuts, and cowpeas. As maize has become more widely cultivated, striga has become an increasingly important maize parasite. Screening methods to assess striga resistance are being developed and several inbred lines and hybrids tolerant to one or more species of striga have been identified, but much additional research on the ecology and control of this pest is needed.

Insects

Stem borers, termites, rootworms and cutworms, and storage insects are a major cause of low maize yields and grain losses after harvest. The trend in sub-Saharan Africa toward greater cropping intensity, the increasing use of minimum or conservation tillage practices, and the growing practice of incorporating crop residues all contribute to rising insect populations. Although many insect pests can be controlled effectively with chemicals, pesticides are often difficult to obtain, particularly for smallholders who lack access to production credit. On the other hand, chemical control is increasingly viewed as undesirable by many policy makers, since improperly used pesticides threaten human safety and damage the environment. Concern for small-scale farmers is particularly great, given their generally poor knowledge about pesticide safety. In view of the implications for human and environmental health, it is likely that the use of toxic chemicals for pest control will eventually be reduced (Mihm and Renfro 1987), and breeding for insect tolerance and resistance is now seen as an integral part of controlling insect pests.

In Africa, where maize grain is frequently stored before it is properly dried and/or without insecticide treatment, insect damage to stored grain can cause losses of 50% or more. Problems with storage pests typically develop as a result of high temperatures and



Source: Rodríguez (1989).

Figure 16. Effect of different soil management practices on maize grain yield, Kamboise, northern Nigeria, 1981.

intermediate humidity, which encourage insect populations to grow. Scientists are developing methods to reduce losses before and after harvest, either through strategies to reduce the buildup of borers, weevils, and other insect pests that attack mature grain in the field or in storage, or by seeking to improve resistance to these insects. Work on improving husk cover (to present a physical barrier to insects) and grain hardness (to inhibit boring) is also underway, and specialists are developing better methods for handling, treating, and storing grain at the farm level after harvest.

Diseases

Maize in sub-Saharan Africa is attacked by numerous fungal, bacterial, and viral diseases. Preliminary CIMMYT data show widespread incidence of ear rots, leaf blight, maize streak virus, and stalk rot. Ear rot is probably the most serious disease, because it reduces the yield and the nutritional value of infected grain and may cause the formation of mycotoxins, a health threat to humans and animals. Leaf blight and maize streak virus also are extremely widespread. More localized diseases include downy mildew, sugarcane mosaic virus, maize chlorotic mottle virus, maize dwarf mosaic virus, curvularia leaf spot, and brown spot.

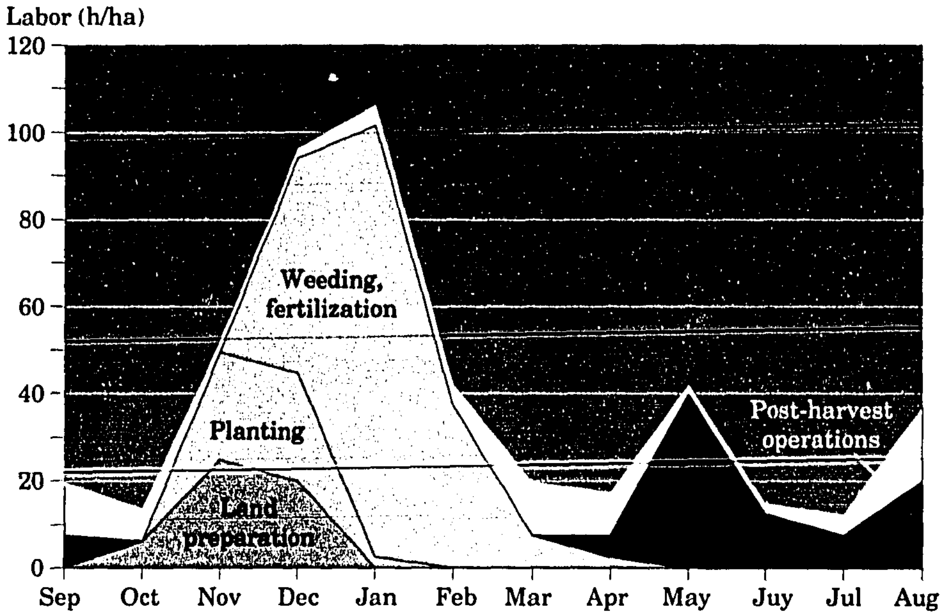
A variety of chemical and cultural practices can help control maize diseases. However, using resistant germplasm is the most cost-effective method for disease control, as well as the least harmful to the environment. Breeding for disease resistance thus remains a primary objective of national and international maize research programs.

Developing materials resistant to maize streak virus receives high priority. Epidemics of maize streak occur periodically in many countries and in all maize-growing ecologies of Africa. The virus is most serious in crops that are planted late, sown during the minor rainy season in bimodal rainfall zones, or grown during the cool season on residual moisture in swampy areas. The international research centers have played a leading role in combatting maize streak. During the 1970s, scientists at IITA pioneered methods for mass rearing the leafhopper that is a vector for the disease; with the help of these methods, IITA, CIMMYT, and national program breeders developed and improved maize populations and varieties with streak resistance. Additional streak research is done at the CIMMYT Maize Research Station outside Harare, Zimbabwe.

Labor Shortages

Shortages of agricultural labor occur throughout many parts of Africa. These shortages tend to be particularly severe if the returns to farm work are low compared to returns to outside employment, for example, in areas where mining offers steady and relatively remunerative work.

While agricultural labor shortages are basically caused by the limited supply of farm workers, two types of competition on the demand side exacerbate the problem. In zones where growing seasons are restricted by rainfall distribution, labor-intensive cropping operations (such as land preparation, planting, weeding, and harvesting) frequently overlap (Figure 17). When this happens, farmers must choose, for example, between planting a larger area and weeding the area that has already been planted.



Source: Malawi Ministry of Agriculture (1977).

Figure 17. Household labor use on maize cropping operations, Chisasa, Malawi, 1972/73.

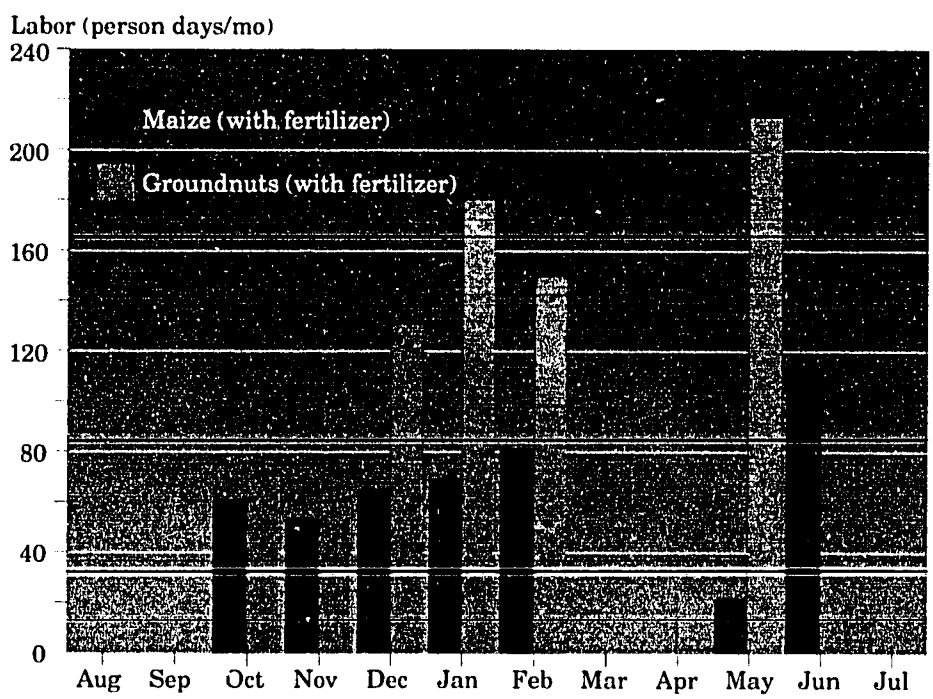
In addition, competition between crops commonly occurs when the demand for labor is at its peak (Figure 18). This competition can have severe consequences for food crops. Faced with allocating scarce labor either to food crops or to high-value cash crops such as groundnuts and cotton, farmers often make the economically rational decision in favoring the cash crops. Many operations for food crops must be postponed or omitted entirely, reducing yields.

Large-scale maize producers can reduce the peak demand for labor by investing in machinery (e.g., tractors to enable earlier and faster planting, and cultivation equipment for weeding). However, the high cost of tractors and their limited utility on unimproved plots generally make them an unattractive investment for small-scale farmers, unless machinery rental services are available. Where grazing capacity is sufficient to support cattle or donkeys (and where trypanosomiasis is not present), animals can substitute for human labor, but many operations must still be performed manually.

Faced with labor constraints, many African maize producers adopt strategies to spread out the demand for labor—for example, intercropping, planting sequentially, and distributing crops between plots with different soils and moisture regimes. Diversification strategies typically reduce maize yields but frequently increase total agricultural output per unit land area and raise overall returns to labor. Also, such strategies tend to reduce the risk of losses if a single component in the cropping system fails.

When evaluating potential production technologies for maize, researchers have not always considered the relationship between the opportunity cost of labor and labor productivity. Productivity increases are generally reported in terms of yield gain per unit land area, rather than in terms of yield gain per unit of labor. However, the latter measure may be more relevant if labor is the limiting factor. New technologies that increase the productivity of land may also increase the productivity of labor and other scarce resources. But if the opportunity cost of agricultural labor is high (for example, because of attractive off-farm employment opportunities), returns to labor invested in yield-increasing technologies for maize may be small or nonexistent (Table 7). Farmers may then decide not to adopt the new technologies, to adopt them only partially, or to adopt them while modifying other practices to accommodate the increased labor requirements.

Work done in Zambia by Ndiaye and Sofranko (1988) illustrates the importance of labor constraints in farmers' decisions to adopt maize technology. The study focused on a sample of farmers who shifted from traditional open-pollinated varieties to hybrids. The authors discovered that farmers' inability to mobilize the additional labor required for managing hybrids resulted in partial adoption and compromises in the performance of recommended practices, such as weeding and earthing up.



Source: MLARR survey data.

Figure 18. Seasonal labor requirements for maize and groundnuts, Makoholi region, Zimbabwe (1985-87 averages).

Of course, not all new technologies increase the demand for labor; some, such as use of chemicals to control weeds, have just the opposite effect. While labor saving technologies theoretically enable farmers to expand their farming operations, the result is not always an increase in agricultural production. Work in Zimbabwe has shown that when off-farm employment is particularly remunerative, maize farmers may use the labor saving effect of a new technology to reduce the cost of satisfying household food requirements, rather than to increase their total output. Thus, technical change in agriculture may not result in a net increase in food production, although it will result in higher total incomes from increased off-farm earnings (Low 1988).

Draft Power Shortages

Draft power can be especially important when labor is in short supply, especially if land must be prepared rapidly to take advantage of scarce rainfall at the beginning of the growing season. As maize based production systems have become more intensive, the adoption of mechanized technologies has increased, beginning in those parts of eastern and southern Africa characterized by a convergence of facilitating technical factors (appropriate soils, flat and open land, absence of trypanosomiasis), economic factors (stable and remunerative markets for maize), historical factors (introduction of draft animals and tractors by settlers), and institutional factors (availability of maintenance and repair services, veterinary services). Mechanization has not been widely adopted in areas where some or all of these facilitating factors are absent, particularly in the forest zone of western and central Africa.

Animal traction is relatively recent in Africa, dating back at most 100 years (except in parts of Ethiopia where the use of draft animals goes back several millennia). The use of animals in African agriculture expanded rapidly with the arrival of European settlers, who practiced animal traction and frequently expropriated large tracts of relatively flat, open land suitable for the plow. In most of eastern Africa, use of draft animals spread relatively slowly to smallholders, who tended to be unfamiliar with animal traction technologies, frequently lacked access to enough land to make them profitable, and in any case were often prohibited from growing the export crops best suited to the use of draft animals. But further to the south, small-scale farmers were more quick to adopt animal traction technologies, particularly the moldboard plow, which by the 1920s was used in parts of Botswana, Lesotho, Swaziland, and Zimbabwe (Yudelman 1964).

In western and central Africa, adoption of animal traction technologies was stimulated by the intensification of agriculture associated with population growth and access to markets. In the northern Guinea savanna of Nigeria, although ox-plow technology had been available since colonial times, it did not become widespread until the 1970s, when improved maize varieties were introduced and fertilizer use became common. Extended fallow periods also disappeared from many areas around that time.

The use of draft animals continues to spread in Africa. Efforts to eradicate the tsetse fly, the vector of trypanosomiasis, have succeeded in reducing the incidence of the disease in some areas and opening them up to animal traction. As with any technological innovation, the rate and degree of adoption is influenced not only by technical considerations, but also by economic factors. Animal traction technologies have often proved profitable in zones where the supply of agricultural labor is limited. In zones where land is abundant, greater use of animal draft power has increased

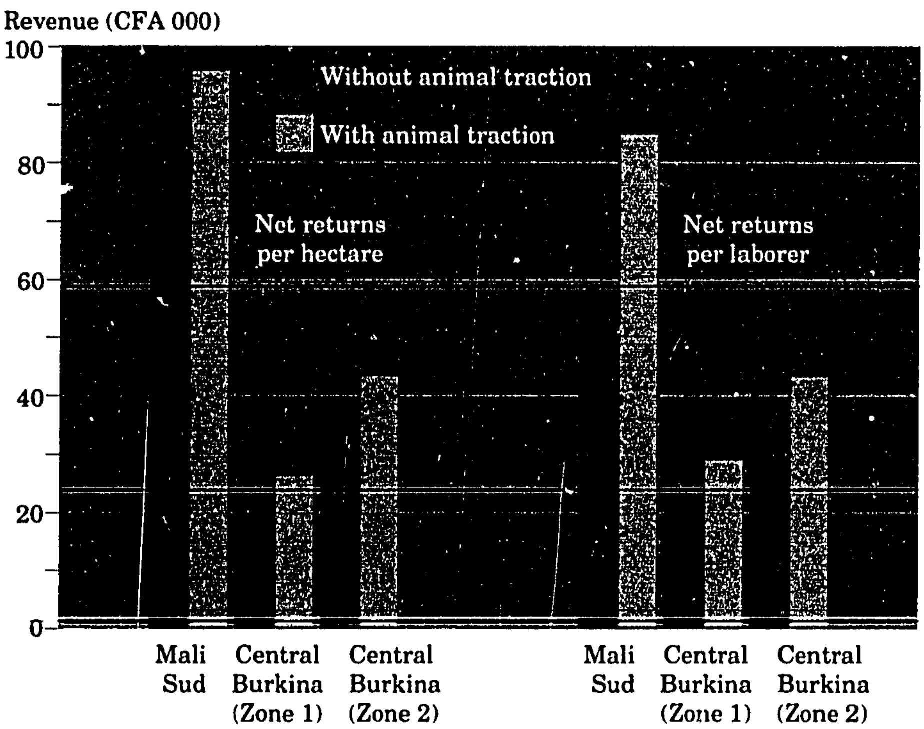
Table 7. Returns to labor for traditional and recommended practices for maize, Mampong-Sekodumasi area, Ghana

	Traditional practice	Recommended practice
Yield (t/ha)	1.10	2.04
Returns to land (cedis/ha)	734	1,386
Total labor inputs (days/ha)	61	106
Returns to labor (cedis/day)	12	13

Source: Bruce et al. (1980).

the area that can be worked by each farming household, leading to higher rural incomes (Figure 19). On the other hand, since many farmers do not own oxen and must wait to use hired animals, plowing and planting may be delayed, so that the effect of the larger area planted may be offset in part by lower yields. In a few more densely populated zones, expansion in total cultivated area has reduced the availability of land for pasture, and the resulting shortage of animal feed resources has created economic incentives for farmers to seek ways to reduce their use of draft animals.

Tractors, which first appeared in Africa in large numbers immediately following World War I, were used almost exclusively by European settlers and on large government farms; not until after World War II did their use spread to African farmers. In eastern and southern Africa, tractors are now used for maize production primarily on large commercial farms, although more smallholders have started to rent tractors, particularly where labor is scarce. However, lack of local manufacturing capacity and maintenance facilities continues to keep operating costs high, restricting adoption in many areas. In western Africa, tractor use for maize production remains much more limited, partly because of technical factors (small fields, fields with stumps) and partly because of economic factors (low profitability of maize, high operating costs).



Source: Pingali et al. (1987).

Figure 19. Effect of animal traction on farm income in the Sahel: change in revenue per hectare and per laborer.

Inadequate Incentives for Producers and Marketing Problems

One reason for the low yields of maize in many parts of Africa is that producers are not always given adequate price incentives. Maize producer prices vary across Africa: some countries maintain prices above the world price, whereas others maintain them below the world price. These policies often change over time as well. Governments that attempt to increase the profitability of maize production by supporting producer prices are often forced to abandon this policy in favorable years, when large marketed surpluses quickly exhaust the funds available to buy and store grain; as a result, producer prices fall precipitously (see "Maize Price Cycles in Eastern and Southern Africa," p. 36). Low producer prices for maize do not necessarily discourage production, since much depends on the prices of alternative crops, but they decrease the likelihood that farmers will look to maize production as an attractive source of income.

In addition to supporting producer prices, African governments have also attempted to stimulate maize production by facilitating marketing. Unfortunately, although public sector participation in maize marketing sometimes improves performance, more often it places a severe financial and administrative burden on the state while improving market performance only marginally. Poorly equipped, inadequately staffed, and underfunded government marketing organizations frequently fail to support and stabilize producer prices or provide guaranteed market outlets. Pan-seasonal and pan-territorial pricing policies, supposedly introduced to raise and stabilize producer incomes, are often counterproductive because they disrupt incentives for private dealers to transport and store grain, with the result that the state assumes these functions at great expense. Economies of scale in transporting, storing, and processing grain often do not materialize because centralized marketing facilities are inefficient and wasteful. Given all of these problems, the results of government participation in maize markets have been mixed at best.

Recent policy changes introduced in many countries to increase the productivity of resources devoted to maize production are intended to bring about the increasing commercialization of smallholder production. If these new policies are to succeed, it will be increasingly important that small-scale farmers have reliable access to market outlets and that governments follow a consistent policy towards marketing and pricing. This will require considerable rethinking of the respective roles of the public and private sectors in maize marketing.

In many African countries, the most desirable level of public sector participation in maize marketing remains an open question. Government marketing organizations address real political and economic needs in countries where the uncertainty of maize production and the difficulties of trade make policy makers reluctant to rely on unregulated private trading to ensure adequate supplies and stable prices. That is why countries of such different political persuasions as Kenya and Tanzania rely extensively on state participation in maize marketing. However, the experience of the past 25 years suggests that the political benefits of public sector participation in maize marketing must be weighed carefully against the high economic costs. Efforts to place maize marketing entirely in the hands of government organizations have often proved inefficient and ineffective, confirming that private traders are better able to perform certain marketing functions. Thus, the challenge facing policy makers is to design effective marketing systems that allow private traders sufficient freedom to exercise their considerable marketing skills while at the same time ensuring the stability that can be provided only by the active participation of public sector organizations.

Realizing the Potential of Maize in Africa

Although it is risky to make precise projections, general orders of magnitude can be estimated for the factors most likely to contribute to future growth in demand for maize in Africa. Population growth will stimulate demand at an annual rate of approximately 3% well into the next century. Income growth is more difficult to predict, especially in view of the disappointing performance of many African economies during the past two decades, but it is perhaps not too optimistic to hope that economic growth of 1-2% per year will resume in many countries before the end of the century. Rising incomes will translate into increasing demand for maize, both as human food and especially as livestock feed. At higher income levels, the demand for maize for food should eventually diminish, but this effect will be more than offset by an increase in demand for maize used as feed and/or in industry.

Population growth, rising incomes, intensification of livestock production, and policy-induced changes in food consumption patterns could contribute to future growth in demand for maize in Africa at a rate of 3-5% per year. Growth in demand of this magnitude is well above historical production growth rates, implying that a significant increase in future supply will be necessary to maintain (or preferably improve) maize self-sufficiency.

Without a doubt, the potential exists for significantly increasing the productivity of resources devoted to maize in Africa, despite the imposing constraints reviewed above. But will maize realize its potential?

This report has shown that the possibility exists for significantly reducing the unit cost of producing maize. If lower production costs are translated into lower market prices—that is, if governments do not intervene to support prices at high levels in an attempt to redistribute income to producers—maize production and consumption can be expected to rise. The crucial implication for policy is that technological change has the potential to resolve *both* the supply and demand problems, since higher productivity will simultaneously increase the profitability of maize to producers and reduce the price paid by consumers. Thus, technological change can lead to the intensification of maize production systems, generation of employment, and growth in income.

Improved technologies are already available to at least double maize yields in many areas, and if these technologies can be transferred to farmers, maize production in Africa could accelerate rapidly. However, transferring technologies to farmers and establishing the stable,

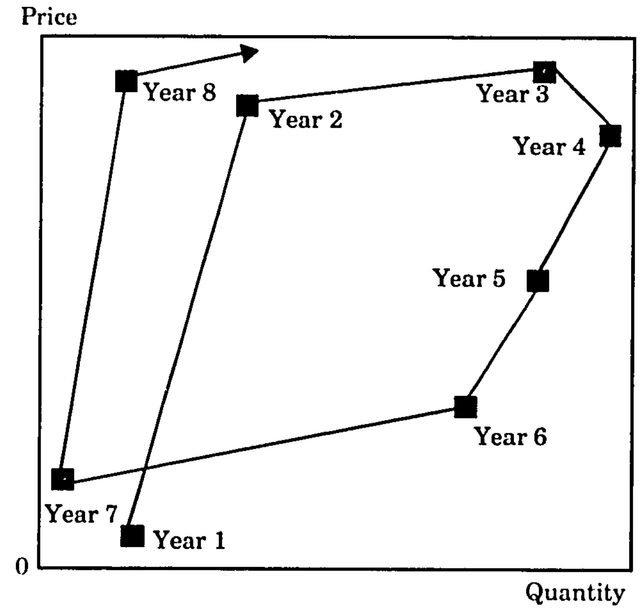
(continued on p. 37)

Maize Price Cycles in Eastern and Southern Africa

Under most state-controlled maize marketing systems, producer prices are announced just prior to the growing season to influence farmers' planting decisions. However, producer prices set in response to short-term market conditions often have undesirable consequences in the long term. One striking example of this process is the maize price cycle observed in recent years in several countries of eastern and southern Africa.

The maize price cycle is a variation of the so-called "cobweb model" of agricultural commodity supply. The basic assumption of the cobweb model is that producers respond to last year's price, which reflected the previous year's supply, which itself represented producers' response to the price the year before, and so on back in time. These delayed responses, which are a result of agriculture's seasonal nature, result in an unstable cyclical relationship between price and quantity produced.

In eastern and southern Africa, the maize price cycle typically begins in a year when drought severely limits production, leading to maize shortages and necessitating high levels of imports to meet domestic demand for food (see Figure). Policy makers respond by sharply raising the producer price of maize. The higher price induces farmers to increase their production the following year, and a large surplus results. In subsequent years, if rainfall is normal, nominal producer prices are kept virtually static, which in the presence of inflation translates into declining real prices. Declining real prices eventually lead to lower production as farmers gradually decrease area planted to maize or reduce their use of purchased inputs. For a time, the government can compensate for declining production by releasing grain from its stocks; thus, the effect of lowered production is concealed with the help of the surplus generated by the original drought-induced rise in prices. But sooner or later a serious drought recurs, causing production to slide again, and shortages reappear. Imports are again necessary to meet domestic food demand; policy makers react by sharply raising the producer price; and the cycle is repeated.



The maize price cycle in eastern and southern Africa.

In Zimbabwe, the maize price cycle has been particularly evident since Independence. When the new government came to power in 1980, maize producer prices had been declining for a number of years, and Zimbabwe was importing maize for the first time in several decades. In the face of depressed production, the government raised the maize producer price 40% higher than the previous year's price and well above prices offered for substitute crops.

With the help of exceptionally favorable weather and factors unrelated to price, such as the end of the civil war and improved distribution of purchased inputs, farmers responded enthusiastically to the price increase. Sales to the official Grain Marketing Board surged from 800,000 t in 1980 to over 2 million tons in 1981. This quantity of maize overwhelmed marketing and storage facilities, and the government was forced to export the surplus at a loss. For the next three years, producer prices remained the same in nominal terms but actually decreased 27% in real terms. Planted area consequently fell, resulting in a steep drop in production (which was exacerbated by drought). In reaction to plummeting maize stocks, the government announced a 30% nominal increase in the 1985/86 producer price. Again, producers responded by producing a huge surplus.

remunerative markets that make adoption profitable will not be easy. Considerable effort—and public sector resources—will have to go into producer education programs and market support activities. In this regard, many problems with maize in Africa appear institutional and financial rather than purely technical: Can farmers be provided with the additional education they need to manage more complex technologies? Can economic incentives be created to increase production? Can effective input delivery systems be designed and implemented? Can stable markets be assured without bankrupting state treasuries?

At the same time, to say that many obstacles to increased maize production are institutional and financial does not imply that all technical problems have been solved. Numerous technical challenges remain to be addressed, especially with regard to sustaining increased yields over the long term in more marginal areas.

The relative paucity of technologies "on the shelf," waiting to be transferred to farmers after minimal modifications, emphasizes the need to improve the quality of trained research staff and to increase the productivity of resources allocated to research. During the past decade, agricultural research has been relatively well funded in Africa, yet technological progress has been modest at best, particularly in food crops (Eicher 1989). Many research administrators have begun to realize that money alone cannot solve all problems; more effort must go into carefully managing resources and targeting expenditures at research that will have a high payoff. For example, it is not enough to establish that drought is a problem requiring additional work. Instead, the implications for research must be carefully thought through. How can drought problems most effectively be addressed? Should research resources be invested in breeding programs designed to develop drought-resistant germplasm, or will higher payoffs be attained if the resources are used to finance crop management research on practices for conserving soil moisture?

The role of policy also requires study. Resolving the constraints on maize production in Africa will certainly require improved technologies, but agricultural research cannot be expected to produce results in the absence of policy reforms. Too often, technological innovations are blocked by inappropriate incentives facing producers, unavailability of inputs, lack of information at the farm level, or excessive delivery costs. If farmers do not know about available technologies, cannot obtain improved inputs, or have no incentives to alter existing practices—or if the government cannot afford to sustain programs that promote production—raising the low levels of maize production will require effective policy reform. Since effective policy reform can only be based on accurate knowledge, research—not necessarily more, but *better*, research—will be required. At the farm or local level, research will be needed to identify key production constraints and to devise policies capable of resolving them. At the national or global level, research will also be needed to help improve our understanding of the factors affecting food consumption patterns, so that policies can be designed to manage production, consumption, and trade.

Finally, the design of new technologies and policies will increasingly have to be undertaken with a view to their effects over more extended time periods. The long-term implications of intensifying maize production in Africa, with its often fragile soils, limited rainfall, and complex farming systems, remain unclear. Past experience suggests that "quick-fix" solutions designed to raise cereal production in response to pressing food shortages often prove unsustainable over the long run. Production technologies must therefore be developed with sustainability in mind. Institutions, especially those governing land tenure arrangements, will have to be adapted as well to accommodate the need to establish sustainable systems for managing soil and water resources.

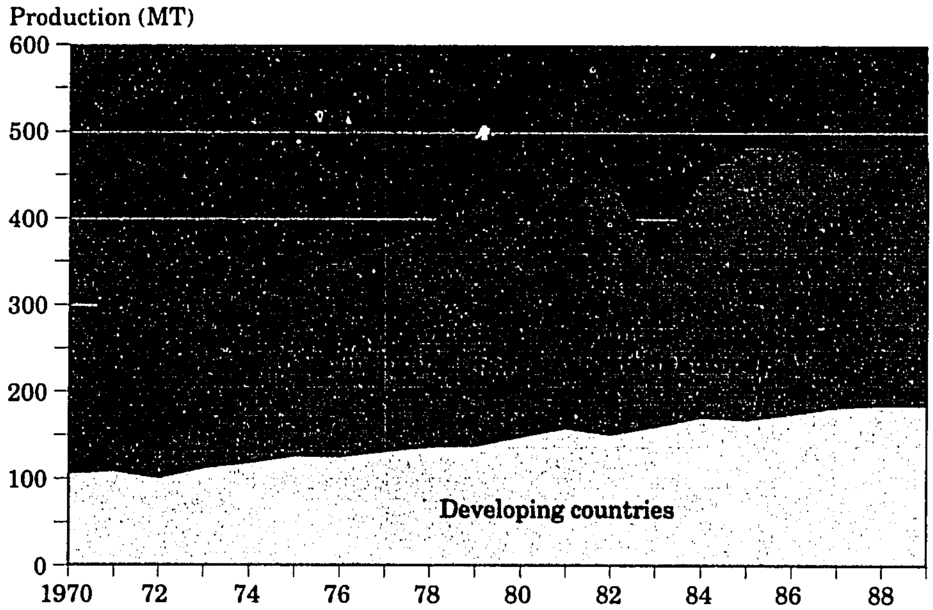
The present challenge—and future possibilities—should not be underestimated. Maize, more than any other crop, offers the promise of meeting Africa's food needs in the years to come. If even a few of the obstacles described in this report can be overcome, there is no reason to believe that the promise will not be fulfilled.

Introduction

World maize production in 1989 is estimated at 472 million tons (MT), an increase of 73 MT (18%) over the previous year.[8] The increase reflects a return to normal production levels in the USA, where drought in 1988 reduced production by a third. In comparison, world maize utilization for 1989/90 is estimated at 470 MT. With estimated production approximately equal to utilization, world maize stocks will remain relatively unchanged, closing at around 89 MT.

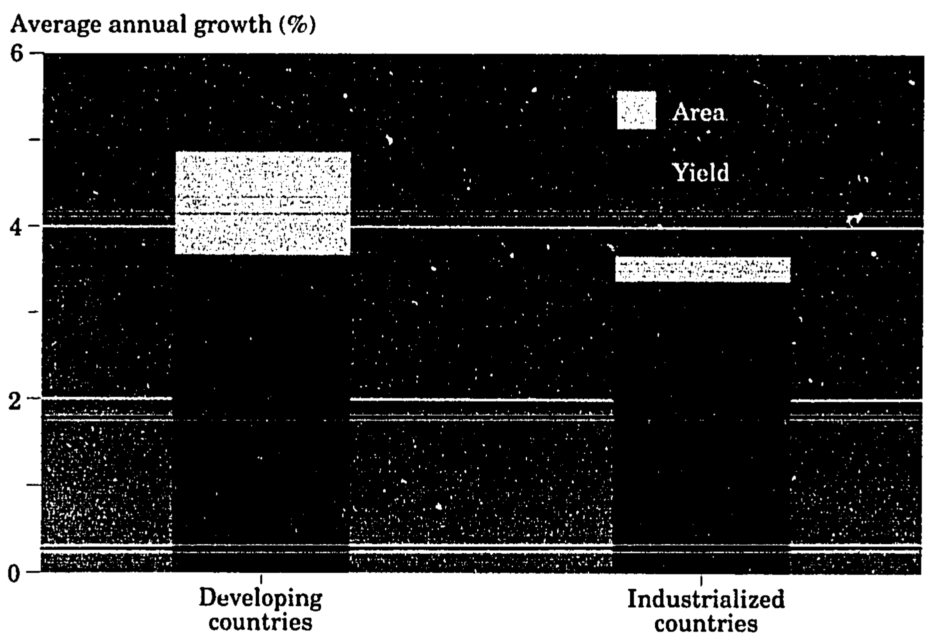
Maize production in developing countries in 1989 is estimated at 184 MT, representing 40% of total world production (Figure 20). While maize production in both industrialized and developing countries continues to grow, the sources of growth are quite different in each group. In developing countries, production is increasing because area and yields are rising, whereas in industrialized countries production has grown primarily because of rising yields, as planted area has expanded very little (Figure 21). Since 1970, total area planted to maize in developing countries has grown at a rate of 1.2% per year, compared to only 0.3% per year in industrialized countries. Although yields in both groups of countries have almost doubled since 1970, average yields in developing countries (2 t/ha) are still only one-third as high as those recorded in industrialized countries (6 t/ha).

8 This information is current as of November 1989.



Source: Calculated from FAO data.

Figure 20. Trends in world maize production, 1970-89.



Source: Calculated from FAO data.

Figure 21. Sources of growth in world maize production, 1970-88.

Production in Developing Countries

Latin America

Maize production in Latin America continues to fluctuate as unstable economic conditions plague some of the region's largest producers. Latin American maize production in 1989 is currently estimated at 51.5 MT (13.4 MT in Central America, including Mexico, and 38.1 MT in South America). Brazil is the region's largest maize producer, with 1989 production estimated at 26 MT. Over the last 20 years, maize area in Brazil has increased at an average rate of 1.9% per year, in contrast to many other Latin American countries, where maize area has declined. Argentina's maize crop is forecast at 7 MT in 1989, down slightly from the previous year. Despite significant reductions in maize export taxes and in import tariffs on herbicides and pesticides, maize production in Argentina is expected to decline further as farmers shift to more profitable oilseed crops. Mexico's maize production continues to decline from the record levels achieved during the mid-1980s; production is estimated at 10 MT for 1989.

Sub-Saharan Africa

Maize production in sub-Saharan Africa benefited from favorable weather for the second consecutive year, and production in 1989 is likely to approach the record level of 18 MT achieved the previous year. Policy reforms have also contributed to these high production levels. In many African countries, overvaluation of domestic currencies discouraged food crop production by lowering the price of imported substitutes, especially wheat and rice. Recent devaluations (sometimes coupled with import restrictions) have encouraged maize producers by reducing the availability and raising the prices of imported cereals. Nigeria's maize crop will increase to 1.9 MT in 1989, continuing the strong growth of recent years. In eastern and southern Africa, maize production continues to fluctuate around an upward trend, notably in Kenya and Ethiopia, which account for 40% of the maize produced in the region.

West Asia and North Africa

Increased maize production in West Asia reflects the effects of higher yields: production for the region in 1989 is estimated at 2.6 MT. Turkey is by far the largest maize producer in West Asia, accounting for 2.2 MT. As improved germplasm has spread, maize yields in Turkey have increased substantially, from around 2 t/ha in the early 1980s to around 4 t/ha in recent years.

In North Africa, maize production also continues to grow as yields improve. Egypt, which produces approximately 90% of the region's maize, harvested 4.3 MT in 1989. Currently Egyptian maize yields average around 4.5 t/ha, mainly because of the extensive irrigated maize area and the considerable use of purchased inputs.

South Asia, East Asia, and Southeast Asia

Maize production continues to grow modestly in South Asia. As arable land becomes increasingly scarce in many of the region's more densely populated countries, the expansion in maize area has started to slow, but intensification continues. India's maize production is estimated at 8 MT in 1989, close to long-term trend levels.

Intensive maize production systems are also becoming more common in East Asia as food and feed demand for maize increases. China, where average maize yields currently stand at 3.8 t/ha, remains the most important producer in the region. Chinese production is estimated at 76 MT in 1989, down slightly from the record level achieved in 1987 when the country's rigid grain procurement system was partially relaxed. During the past 10 years, maize production in China has increased at the impressive rate of 4.3% per year, owing largely to yield gains resulting from the adoption of improved germplasm and higher levels of fertilizer.

In Southeast Asia, expanding area and rising yields have enabled maize production to increase rapidly. Indonesia has maintained its position as the region's largest producer; 1989 production is estimated at 5 MT, around 40% of regional production. The Philippines with 4.5 MT rank second in production, and Thailand is third with 4 MT. Yields in Thailand and Indonesia are higher than in the Philippines (2.3 t/ha and 1.9 t/ha vs 1.1 t/ha), but the Philippine maize area is greater, largely because growing demand for maize for feed has encouraged farmers to increase plantings.

Production in Industrialized Countries

Maize production in industrialized countries (including Eastern Europe and the USSR) is estimated at 288 MT for 1989. This represents an impressive increase of 72 MT (33%) over the abnormally small harvest of the previous year. Maize production in the USA, which accounts for nearly 40% of total world output, is estimated at 193 MT in 1989, up from 125 MT in 1988. The surge in US production was made possible by an increase in area planted, as well as by higher yields, which in 1989 returned to normal levels (around 7 t/ha) after the 1988 drought. Adjusting for short-term variability in production caused by the weather, average maize production levels in the USA at the end of the 1980s roughly equal those of the late 1970s, as yield increases have been offset by area reductions.

In the European Community (EC), 1989 maize production is estimated at 26 MT. Two countries dominate EC maize production: France accounts for almost half of the total, Italy for an additional one-fourth. Maize area in the EC totalled 3.9 million hectares in 1989, down only slightly from the previous year despite efforts by EC governments to curb production.

Eastern European maize production has increased steadily over the past 20 years, mostly because yields have improved. The largest producers of maize in eastern Europe are the USSR and Romania, which together on average account for 60% of the region's production. Production in the USSR is estimated at 15 MT in 1989, down slightly from the previous year. Production in Romania has declined sharply from the 1986 record harvest of 20 MT to an estimated 14 MT in 1989.

Trade Projections for 1989/90

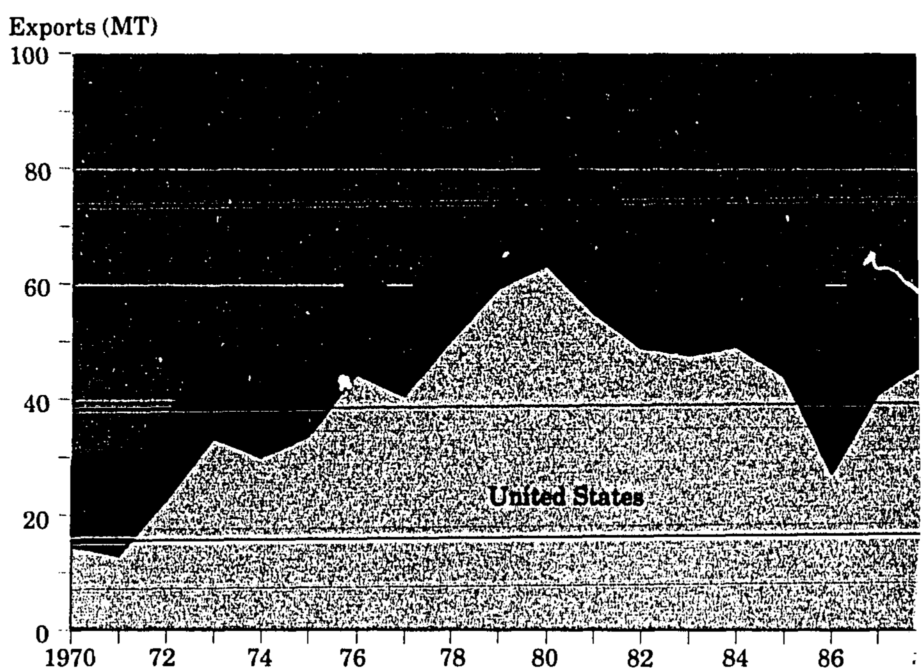
World maize trade in 1989/90 is forecast at 68 MT. This represents the fourth consecutive annual increase in the volume of maize traded since 1986/87, when trade volume fell to 56 MT after exceptionally favorable production conditions in a number of influential importing countries reduced demand considerably.

Principal Exporters

The five leading exporters of maize in 1989/90 include the USA (74% of world market share), South Africa (7%), China (5%), Argentina (4%), and the EC (2%). Maize exports from the USA are estimated at 51 MT for 1989/90.

Even though the USA continues to dominate world maize trade (Figure 22), other leading maize exporters have experienced considerable change. For example, Argentina's maize exports have declined steadily since 1986/87, when they reached 5.6 MT, or 10% of the world market. Unable to compete with the export subsidies offered by the US and the EC, Argentina has seen its rank in the world export market fall from second to fourth.

Maize exports from South Africa are forecast at 4.6 MT in 1989/90, a level last seen in the early 1980s. White maize, which accounts for 65% of South African exports, usually finds buyers within southern Africa, whereas yellow maize is normally sold to Japan, Taiwan,



Source: Calculated from FAO data.

Figure 22. Trends in world maize exports, 1970-88.

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South Korea, Turkey, and Iran. In most years, white maize is scarce in global markets and commands a price premium, especially among African importers. However, in 1989 excess production throughout much of southern Africa reduced demand for imports, and white maize from South Africa was sold at a discount.

Maize exports from China and Thailand declined in 1989/90 owing to reduced availability. China will export about 3.3 MT in 1989/90, down 12% from the previous year; Thailand's exports are expected to be the smallest in the last 20 years. Domestic feed utilization of maize in Thailand has been increasing by 12-15% annually since 1985/86 because of rapid income growth. As reduced Thai exports raise the price of Thai maize US$ 15-20 above world prices, traditional buyers such as Malaysia and the Philippines are seeking new suppliers.

Principal Importers

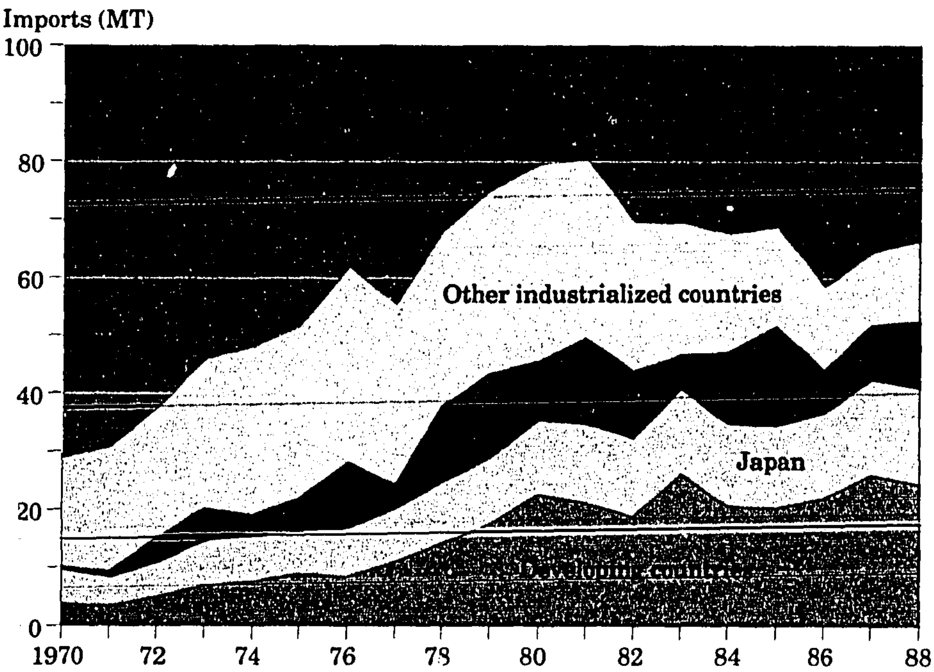
The five leading importers of maize in 1989/90 include the USSR (accounting for 26% of world imports), Japan (24%), Korea (9%), Taiwan (6%), and Mexico (5%).

Japan has been the world's largest importer of coarse grains since the mid-1960s, although it is surpassed occasionally by the USSR in years when Soviet production is excessively low (Figure 23). Maize imports into Japan, estimated at 16 MT for 1989/90, have slowed recently, which perhaps signals a decline in Japanese demand for feed grain brought about by increasing imports of meat. From 1986 to 1988, Japanese meat imports rose by around 50%, because trade barriers erected to protect the domestic beef industry were reduced.

Soviet imports of maize for 1989/90 are estimated at 17.7 MT, slightly less than the previous year, but still well above the long-term average. The sharp increases in coarse grain imports by the USSR since the mid-1970s can be attributed to slow growth in domestic cereal production, continued high prices for feed wheat, and efforts to improve the availability of livestock products to Soviet consumers. Unusually high levels of Soviet maize imports account for most of the recent increase in global maize trade. However, large maize imports into the USSR may not continue indefinitely, since the USSR historically has imported grain only to supplement temporary shortfalls.

Maize imports into Korea and Taiwan have increased steadily since the mid-1960s, mostly to supply rapidly growing livestock industries.

Unlike Asian and European importers, Mexico imports maize primarily for food (although imported maize is fed to livestock when sorghum is unavailable or very expensive). Maize imports into Mexico are forecast at 3.5 MT in 1989/90. Mexico's increasing reliance on imported maize reflects stagnating domestic production, as well as the rising demand that is a consequence of rapid population growth and large consumer price subsidies.



urce: Calculated from FAO data.

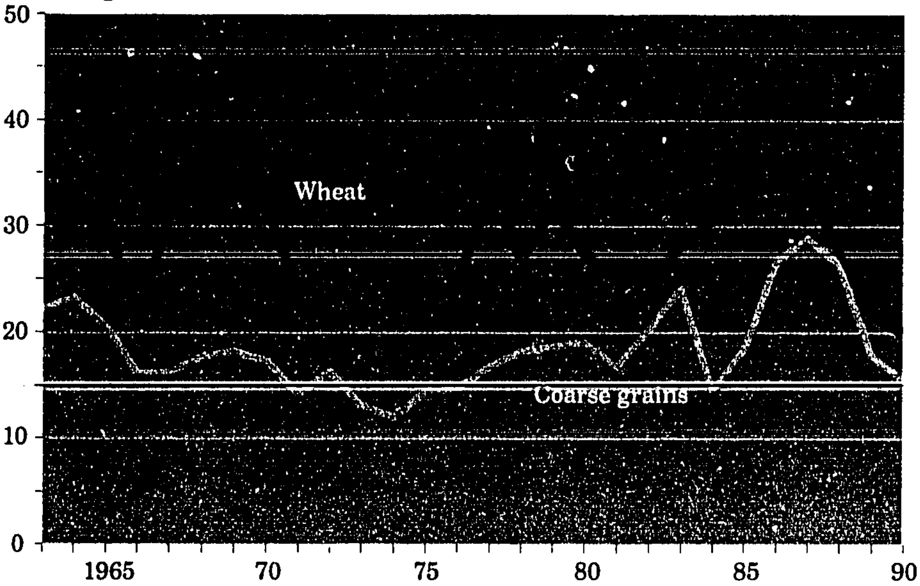
gure 23. Evolution of world maize imports, 1970-88.

Stocks, Prices, and Utilization

During recent years, world maize stocks and prices have fluctuated greatly. World coarse grain stocks ranged from a low of 111 MT in 1984 (approximately 15% of annual consumption requirements) to a high of 234 MT in 1987 (approximately 29% of annual consumption requirements) (Figure 24).[9] World maize prices in nominal terms have fluctuated considerably, reaching a high of 139 US$/t in 1984 and falling to a low of 76 US$/t in 1987.

Since the USA accounts for two-thirds of world maize production and stocks, much of the variability in maize prices and stock levels can be attributed to the combined effects of weather and government policy in the USA. During the last 20 years, both of these factors have been unusually variable. Repeated droughts (in 1970, 1974, 1980, 1983, and 1988) have coincided with major changes in farm policies. The resulting production instability led to large fluctuations in maize stocks and export prices.

The effects of the North American drought of 1988 are still felt in world maize markets, as lower production in the USA has reduced stocks. World stocks of coarse grains are expected to stand at 127 MT at the end of 1990, approximately 16% of annual consumption requirements (Figure 24). While these stock levels are below long-run trends, the fear of an impending world maize shortage is probably unfounded, since extensive unplanted area in industrialized countries—particularly the USA—can quickly be brought back into production. Global maize supplies would be threatened only by another drought as severe as that of 1988, but the probability that this will happen in consecutive years is extremely low.



Source: Calculated from USDA data.

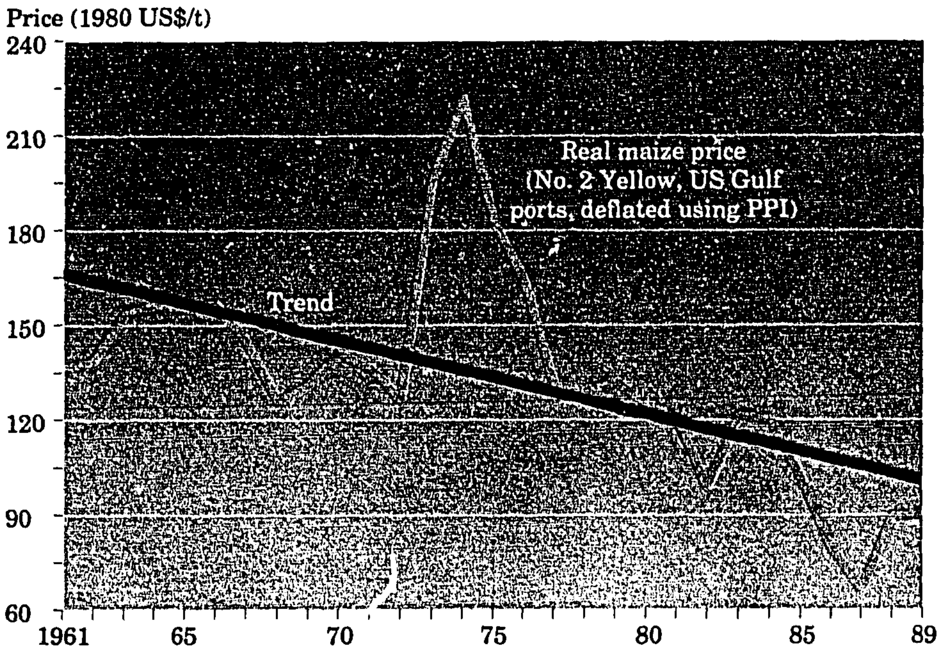
Figure 24. World coarse grain and wheat stocks as a percentage of utilization.

Adjusting for inflation, real maize export prices have not risen to levels seen as recently as 1984; in fact, at the end of 1989 the most commonly cited export reference price was still below the long-term trend (Figure 25). But even though real maize prices remain below long-term trend prices, maize and wheat prices have both risen nearly 50% in nominal terms during the past two years, presenting a serious problem for developing countries that rely on cereal imports to meet their food requirements. For countries importing from the USA, this effect has been amplified as the USA has cut back on aggressive export programs that extended subsidies to many importers. Furthermore, as cereal prices increase, the cost to donors of providing food aid also increases, and sometimes the amount of food aid is reduced. In 1988/89, total food aid shipments decreased by 30% to their lowest level since 1983/84. Fortunately, this decline coincided with record grain harvests in sub-Saharan Africa, the recipient of most of the world's food aid, so the effects of the decline in aid were somewhat mitigated.

Outlook

During the 1980s, the world maize economy has been buffeted by a number of shocks that have affected supply. Successive droughts in major producing countries, coupled with abrupt agricultural policy changes in both exporting and importing countries, have led to considerable fluctuations in world maize production. These fluctuations are manifested in international maize markets in the form of supply and price instability.

9 In many countries, data on maize stocks are not reported separately from data on coarse grain stocks. This section describes recent developments in coarse grain stocks, which are comprised largely of maize.



Source: Calculated from USDA data.

Figure 25. Evolution of the real price of maize in international markets.

It is difficult to say whether this pattern will continue. The weather remains fairly unpredictable, of course, but even policy developments are difficult to anticipate. In recent years, major maize exporters such as the USA and the EC have failed to adopt consistent policies egarding maize production, pricng, storage, and trade. Efforts to ontrol overproduction by supportng domestic producer prices and educing area have not always ucceeded, forcing governments to esort to aggressive export subsidy nd food aid programs to dispose of rpluses. These actions have often acerbated weather-induced stability by increasing supply and ice uncertainty in world markets.

ttle can be done to control the eather, but agricultural policies n be changed. Although specific licy developments are impossible predict with confidence, several trends will undoubtedly condition the future policy environment. As the cost of agricultural support programs in industrialized countries continues to rise, policy makers will come under increasing pressure to decrease subsidies. Until now, despite considerable rhetoric, few concrete actions have been taken to implement significant changes. This situation may be changing. At the close of the midterm review of the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) trade negotiations, representatives from many of the world's leading maize producers agreed to long-term reductions in agricultural support and protection. Some of these countries seem to be following up on this pledge. For example, the EC and the USA announced a 3% reduction in producer prices for maize in 1990/91. Thus there is reason to believe that in coming years agricultural policies in the USA and the EC will reduce production of cereal crops, including maize.

Notwithstanding the strong economic reasons for the USA and EC to discontinue their costly support policies, future developments in these two countries will be heavily influenced by political forces. If overproduction is not curbed, programs to promote exports could conceivably resume and lead to lower prices in world markets. Alternatively, if chronic surpluses are eliminated, export volumes could decline, reducing supplies and raising prices in world markets.

On the demand side, the picture is equally clouded. Several large importers of maize (or potential importers) are undergoing changes that could affect their future demand for maize. China seems to be losing ground in its effort to achieve self-sufficiency in cereals; if present trends continue, China could become increasingly dominant in world maize markets. The USSR also appears to be having trouble meeting its feed grain requirements from domestic production. With the recent opening of the Soviet economy, it is unclear how cereal production will be affected, but if efforts continue to increase production of livestock products, future growth in feed grain imports—both maize and wheat—is a distinct possibility. Japan's future role in the international maize market also remains unclear, although the recent relaxation of controls on beef imports is likely to have a negative effect on Japanese feed imports in the short run. Future growth in demand for maize could also come from a number of developing countries which currently are not major maize importers, assuming income growth leads to growth in demand for livestock products.

The tables that follow present 36 statistics related to maize production, trade, utilization, and prices, as well as some basic economic indicators. The statistics were selected to provide the latest available information.

Countries listed in the tables are classified as either maize producers or consumers. Maize consumers include developing countries consuming over 100,000 tons of maize per year and industrialized countries c..suming more than 1 million tons of maize per year from 1985 to 1987. Maize producers include developing countries in which maize production exceeded 100,000 t/yr from 1985 to 1987 or accounted for 50% of total maize consumption, and industrialized countries in which maize production exceeded 1 million tons per year from 1985 to 1987 or accounted for 50% of total maize consumption. Unless otherwise indicated, the regional aggregates given in the last table include all of the countries of a particular region (for definition of world regions, see Annex 1, p. 68).

All prices reported in the tables were converted to US dollars at official exchange rates.

Notes on the Variables

Variable 1: The source of this information was the FAO tapes of population statistics (1988).

Variables 2-3: The source of these data was the World Bank *World Development Report* (1989).

Variables 4-14, 16-19: The source of these data was the FAO tapes of production statistics (198‾). Growth rates were calculated using the standard formula for annual percentage compound growth:

$$X_t = X_o [1 + (g/100)]^t$$

Where:

X_t = three-year moving average of data for ending period

X_o = three-year moving average of data for base period

t = number of years from the midpoint of base period to that of ending period

g = three-year moving average annual percent growth rate

Variables 20-27: The sources of these data were the FAO tapes of trade statistics (1988) and the FAO Commodities and Trade Division 1987 computer printout. Net imports were calculated as imports minus exports. Negative numbers indicate that the country is a net exporter. Utilization was calculated as production plus net imports. Growth rates were calculated using the standard formula given above.

Variables 28-31: These data (which are for 1988/89) were collected through a general country survey of knowledgeable maize scientists. Some data were estimated by CIMMYT staff. Regional totals and regional averages in some instances are based on data from a subset of countries in the region. Regional data are reported only when information was available for at least 50% of the area in the region (or 50% of maize production, depending on the variable).

Variables 32-33: The source for these data was the World Bank *World Development Report* (1989). Data reported are total fertilizer applied per hectare to arable land and permanent crops.

Variables 15 and 34-36: These data were collected through a general country survey of maize scientists and economists. Data for the majority of the countries refer to the maize crop harvested in 1988/89, although in some cases 1987/88 is the reference year. The maize price is the postharvest price received by farmers. The nitrogen price is usually the price paid by farmers for the most common nitrogenous fertilizer. In some countries, the price of compound fertilizer only was available, and variable 35 refers to the price of nutrients, whether N, P_2O_5, and/or K_2O.

		Producers				
		Angola	Burundi	Ethiopia	Kenya	Madagascar
General indicators	1. Estimated population, 1989 (million)	9.7	5.3	46.1	24.0	11.6
	2. Estimated growth rate of population, 1987-2000 (%/yr)	2.8	3.2	3.1	3.9	3.0
	3. Per capita income, 1988 (US$)	..	230	120	360	180
	4. Per capita cereal production, 1986-88 (kg/yr)	39	87	131	158	217
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	-6.4	0.7	-0.2	-4.0	-2.1
Maize production	6. Maize area harvested, 1986-88 (000 ha)	850	135	956	1,410	143
	7. Maize yield, 1986-88 (t/ha)	0.3	1.3	1.7	2.1	1.1
	8. Maize production, 1986-88 (000 t)	283	179	1,636	2,971	154
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	1.5	1.3	-0.1	3.0	-0.1
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	2.1	1.2	1.7	-1.3	2.1
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	-1.6	1.1	2.7	2.0	0.0
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	-5.7	0.9	1.5	1.7	-0.2
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	-0.1	2.4	2.6	5.1	0.1
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	-3.8	2.1	3.2	0.4	1.9
	15. Estimated percentage white maize, 1988-89 (%)	..	100	97	97	0
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	88	39	19	78	11
	17. Average yield of all cereals, 1986-88 (t/ha)	0.4	1.3	1.2	1.9	1.8
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	-1.4	1.2	1.7	1.7	0.2
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	-5.2	0.9	1.4	1.2	-0.1
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	60	0	20	-225	-2
	21. Net imports of maize per capita, 1986-88 (kg/yr)	7	0	0	-10	0
	22. Per capita total maize utilization, 1986-88 (kg/yr)	37	36	38	124	14
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	-0.3	0.8	0.2	1.0	-2.4
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	-4.0	-0.3	1.2	-3.3	-1.1
	25. Percentage food use of maize, 1985-87 (%)	84	92	81	85	89
	26. Percentage feed use of maize, 1985-87 (%)	3	2	0	2	3
	27. Percentage other use of maize, 1985-87 (%)	13	6	19	13	9
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	..	90	84	35	96
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	..	10	10	10	4
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	..	0	6	55	0
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	100	35	45	..
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	..	2	7	52	2
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	..	10.0	19.1	5.0	-5.9
Key prices	34. Farm price of maize, 1988/89 (US$/t)	..	173	116	122	70
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	..	2.7	5.2	9.1	1.8
	36. Farm wage in kg of maize per day, 1988/89	..	4	8	9	10

Data unavailable or incomplete.

Eastern and Southern Africa (continued)

		Producers				
		Malawi	Mozambique	Namibia	Rwanda	Somalia
General indicators	1. Estimated population, 1989 (million)	8.2	15.3	..	7.0	7.3
	2. Estimated growth rate of population, 1987-2000 (%/yr)	3.5	3.2	..	3.8	3.0
	3. Per capita income, 1988 (US$)	160	100	..	310	170
	4. Per capita cereal production, 1986-88 (kg/yr)	180	35	58	43	86
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	-2.9	-5.5	-1.4	-0.6	3.9
Maize production	6. Maize area harvested, 1986-88 (000 ha)	1,197	600	100	81	238
	7. Maize yield, 1986-88 (t/ha)	1.1	0.5	0.5	1.3	1.4
	8. Maize production, 1986-88 (000 t)	1,305	314	48	108	331
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	1.5	3.9	-0.3	6.5	-1.2
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	1.1	-0.5	0.3	2.4	7.9
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	1.5	-2.6	0.9	-1.2	1.1
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	-0.1	-2.0	0.0	1.8	2.8
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	3.0	1.2	0.6	5.2	-0.1
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	1.0	-2.5	0.3	4.2	10.9
	15. Estimated percentage white maize, 1988-89 (%)	100	..	..	..	100
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	94	69	50	32	33
	17. Average yield of all cereals, 1986-88 (t/ha)	1.1	0.6	0.5	1.1	0.8
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	1.7	-1.6	1.2	-2.0	2.4
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	-0.1	-2.0	0.2	0.6	1.6
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	1	175	..	1	37
	21. Net imports of maize per capita, 1986-88 (kg/yr)	0	12	..	0	5
	22. Per capita total maize utilization, 1986-88 (kg/yr)	171	34	28	17	54
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	0.3	-1.4	-1.9	1.9	-0.6
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	-2.4	-0.8	-2.7	0.9	4.8
	25. Percentage food use of maize, 1985-87 (%)	83	90	88	90	88
	26. Percentage feed use of maize, 1985-87 (%)	5	0	2	2	0
	27. Percentage other use of maize, 1985-87 (%)	13	10	10	8	12
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	94	..	..	..	97
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	2	..	..	..	3
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	5	..	..	..	0
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	33	..	..	..	..
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	13	2	..	2	2
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	5.9	-0.9	..	12.6	-2.[illegible]
Key prices	34. Farm price of maize, 1988/89 (US$/t)	64	158	..	..	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	11.3	..	..	..	..
	36. Farm wage in kg of maize per day, 1988/89	5	..	..	..	..

.. Data unavailable or incomplete.

		Producers				Consumers		Regional total or average
		Tanzania	Uganda	Zambia	Zimbabwe	Lesotho	Swaziland	
General indicators	1. Estimated population, 1989 (million)	26.3	17.8	8.1	9.4	1.7	..	228.1
	2. Estimated growth rate of population, 1987-2000 (%/yr)	3.4	3.3	3.5	3.0	2.6	..	3.2
	3. Per capita income, 1988 (US$)	160	280	290	660	410	790	249
	4. Per capita cereal production, 1986-88 (kg/yr)	159	63	194	279	99	148	131
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	1.9	-7.1	-4.7	-1.4	-4.2	-2.2	-1.8
Maize production	6. Maize area harvested, 1986-88 (000 ha)	1,665	302	640	1,275	148	65	9,871
	7. Maize yield, 1986-88 (t/ha)	1.5	1.0	2.1	1.5	0.7	1.5	1.4
	8. Maize production, 1986-88 (000 t)	2,495	315	1,373	1,910	102	99	13,662
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	1.9	6.1	1.4	1.9	-2.6	-1.1	1.9
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	2.9	-2.9	-4.8	2.9	2.5	0.1	0.6
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	2.4	1.7	3.9	4.7	0.6	11.2	2.2
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	3.5	-1.8	4.1	-1.3	-1.6	1.1	0.8
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	4.3	7.9	5.3	6.7	-2.0	10.0	4.2
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	6.5	-4.7	-0.9	1.6	0.8	1.2	1.4
	15. Estimated percentage white maize, 1988-89 (%)	100	..	100	93	85	99	96
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	57	36	86	69	60	96	38
	17. Average yield of all cereals, 1986-88 (t/ha)	1.3	1.3	2.0	1.3	0.7	1.6	1.1
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	1.4	2.6	3.6	3.9	0.5	10.0	1.3
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	3.0	-0.2	4.3	0.1	-2.1	1.2	0.1
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	-75	0	66	-345	46	12	-155
	21. Net imports of maize per capita, 1986-88 (kg/yr)	-3	0	9	-39	28	17	-1
	22. Per capita total maize utilization, 1986-88 (kg/yr)	99	19	190	177	91	156	63
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	1.8	4.9	2.1	1.8	-3.5	7.1	1.3
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	2.1	-7.9	-3.6	0.6	1.1	-0.7	-1.0
	25. Percentage food use of maize, 1985-87 (%)	92	58	79	64	82	65	81
	26. Percentage feed use of maize, 1985-87 (%)	2	8	3	22	7	14	5
	27. Percentage other use of maize, 1985-87 (%)	7	34	17	14	11	21	13
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	83	65	54	0	14	25	60
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	6	35	1	0	12	0	6
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	11	0	45	100	74	75	34
	31. Fertilizer applied to maize, 1988-89 (kg nutrients/ha)	70	..	75	62	44	37	54
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	8	..	15	57	13	..	11
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	5.9	..	4.5	1.6	17.4	..	4.1
prices	34. Farm price of maize, 1988/89 (US$/t)	92	..	125	98	145	142	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	6.0	..	2.8	7.2	..	4.9	..
	36. Farm wage in kg of maize per day, 1988/89	5	..	10	17	21	14	..

.. Data unavailable or incomplete.

Western and Central Africa

		Producers				
		Benin	Burkina Faso	Cameroon	Côte d'Ivoire	Ghana
General indicators	1. Estimated population, 1989 (million)	4.6	8.8	11.0	12.0	14.6
	2. Estimated growth rate of population, 1987-2000 (%/yr)	2.9	2.9	3.2	3.6	3.0
	3. Per capita income, 1988 (US$)	340	230	1,010	740	400
	4. Per capita cereal production, 1986-88 (kg/yr)	113	226	90	97	71
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	1.2	1.7	-2.5	-0.7	-0.1
Maize production	6. Maize area harvested, 1986-88 (000 ha)	443	206	440	620	487
	7. Maize yield, 1986-88 (t/ha)	0.8	0.8	0.9	0.7	1.2
	8. Maize production, 1986-88 (000 t)	358	171	397	434	571
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	-2.4	-4.3	1.7	5.6	4.2
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	3.8	5.6	-2.0	2.5	4.6
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	2.7	0.6	2.2	-2.4	0.3
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	1.2	1.3	-0.5	3.2	0.0
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	0.2	-3.8	3.9	3.1	3.9
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	5.0	6.9	-2.5	5.8	4.6
	15. Estimated percentage white maize, 1988-89 (%)	..	15	..	..	..
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	73	8	47	49	47
	17. Average yield of all cereals, 1986-88 (t/ha)	0.8	0.7	1.0	0.9	0.9
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	2.8	0.3	1.3	0.2	0.0
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	1.1	2.7	0.9	1.1	0.5
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	0	3	10	16	9
	21. Net imports of maize per capita, 1986-88 (kg/yr)	0	0	1	1	1
	22. Per capita total maize utilization, 1986-88 (kg/yr)	83	21	39	40	42
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	-1.9	-4.7	1.7	-0.9	1.7
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	1.9	4.1	-4.9	1.2	1.8
	25. Percentage food use of maize, 1985-87 (%)	72	94	50	75	84
	26. Percentage feed use of maize, 1985-87 (%)	3	1	12	9	5
	27. Percentage other use of maize, 1985-87 (%)	25	5	38	15	11
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	90	85	81	90	70
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	10	15	18	10	30
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	0	0	1	0	0
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	..	60	..	..
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	6	6	8	8	3
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	3.6	20.7	5.1	0.7	4.7
Key prices	34. Farm price of maize, 1988/89 (US$/t)	..	150	100	125.4	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	..	1.7	7.3	5.8	..
	36. Farm wage in kg of maize per day, 1988/89	..	2	50	19	..

.. Data unavailable or incomplete.

Section	Indicator	Mali	Nigeria	Senegal	Togo	Zaire	Regional total or average
		Producers					
General indicators	1. Estimated population, 1989 (million)	9.1	108.6	7.2	3.4	34.8	250.8
	2. Estimated growth rate of population, 1987-2000 (%/yr)	3.0	3.0	3.1	3.1	3.1	3.0
	3. Per capita income, 1988 (US$)	230	290	630	370	170	359
	4. Per capita cereal production, 1986-88 (kg/yr)	228	107	141	131	35	108
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	1.5	-1.4	-0.4	1.5	0.5	-0.6
Maize production	6. Maize area harvested, 1986-88 (000 ha)	126	1,472	102	230	874	5,295
	7. Maize yield, 1986-88 (t/ha)	1.6	1.1	1.1	0.9	0.8	1.0
	8. Maize production, 1986-88 (000 t)	208	1,638	116	198	729	5,080
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	-2.6	-3.4	1.1	-3.5	2.7	0.0
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	3.1	4.6	6.4	6.6	2.3	3.0
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	0.3	2.7	1.7	7.3	0.7	1.3
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	5.2	-0.2	2.2	-1.7	1.3	0.8
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	-2.3	-0.8	2.8	3.5	3.4	1.3
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	8.5	4.3	8.8	4.8	3.6	3.8
	15. Estimated percentage white maize, 1988-89 (%)	..	90	20	100	..	..
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	6	14	8	44	65	18
	17. Average yield of all cereals, 1986-88 (t/ha)	1.0	1.1	0.8	0.8	0.8	0.9
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	-0.2	1.7	1.1	5.7	0.7	0.9
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	2.2	2.2	1.7	-0.7	1.2	1.3
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	8	17	6	0	27	198
	21. Net imports of maize per capita, 1986-88 (kg/yr)	1	0	1	0	1	1
	22. Per capita total maize utilization, 1986-88 (kg/yr)	25	16	18	63	23	22
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	-1.4	-3.9	0.2	0.6	2.6	-0.8
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	4.3	1.0	2.6	1.7	-1.9	0.2
	25. Percentage food use of maize, 1985-87 (%)	91	66	87	80	83	74
	26. Percentage feed use of maize, 1985-87 (%)	0	15	4	1	4	9
	27. Percentage other use of maize, 1985-87 (%)	9	19	9	19	13	17
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	64	78	0	100	85	80
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	36	20	100	0	15	19
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	0	2	0	0	0	1
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	55	5	..	..	..
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	17	9	4	8	2	6
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	11.1	27.2	5.5	22.6	4.0	10.2
[illegible] prices	34. Farm price of maize, 1988/89 (US$/t)	117	238	200	187	120	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	2.2	5.6	2.9	1.2	5.4	..
	36. Farm wage in kg of maize per day, 1988/89	21	9	17	4	2	..

.. Data unavailable or incomplete.

North Africa

			Producers	
			Egypt	Morocco
General indicators	1.	Estimated population, 1989 (million)	52.7	24.5
	2.	Estimated growth rate of population, 1987-2000 (%/yr)	2.3	2.4
	3.	Per capita income, 1988 (US$)	650	750
	4.	Per capita cereal production, 1986-88 (kg/yr)	177	289
	5.	Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	-1.6	0.8
Maize production	6.	Maize area harvested, 1986-88 (000 ha)	761	380
	7.	Maize yield, 1986-88 (t/ha)	4.5	0.8
	8.	Maize production, 1986-88 (000 t)	3,458	301
	9.	Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	0.9	-0.3
	10.	Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	0.4	-1.4
	11.	Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	1.7	-0.7
	12.	Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	2.0	0.4
	13.	Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	2.6	-1.0
	14.	Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	2.4	-1.0
	15.	Estimated percentage white maize, 1988-89 (%)	..	..
	16.	Maize area as a percentage of total cereal area, 1986-88 (%)	40	7
	17.	Average yield of all cereals, 1986-88 (t/ha)	4.7	1.3
	18.	Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	1.2	0.6
	19.	Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	1.4	2.7
Trade and utilization	20.	Net imports of maize, 1986-88 (000 t)	1,823	204
	21.	Net imports of maize per capita, 1986-88 (kg/yr)	36	9
	22.	Per capita total maize utilization, 1986-88 (kg/yr)	105	22
	23.	Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	0.6	-1.6
	24.	Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	2.2	0.2
	25.	Percentage food use of maize, 1985-87 (%)	44	40
	26.	Percentage feed use of maize, 1985-87 (%)	48	49
	27.	Percentage other use of maize, 1985-87 (%)	8	11
Maize types and productivity factors	28.	Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	36	90
	29.	Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	54	10
	30.	Area planted to hybrids as a percentage of total maize area, 1988 (%)	10	0
	31.	Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	..
	32.	Fertilizer applied to all crops, 1986 (kg nutrients/ha)	319	38
	33.	Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	5.7	7.7
Key prices	34.	Farm price of maize, 1988/89 (US$/t)	..	..
	35.	Ratio of farm-level nitrogen price to maize price, 1988/89	..	..
	36.	Farm wage in kg of maize per day, 1988/89	..	..

.. Data unavailable or incomplete.

		Consumers			Regional total or average
		Algeria	Libya	Tunisia	
General indicators	1. Estimated population, 1989 (million)	24.6	4.4	8.0	114.2
	2. Estimated growth rate of population, 1987-2000 (%/yr)	3.1	3.5	2.1	2.5
	3. Per capita income, 1988 (US$)	2,450	5,410	1,230	1,279
	4. Per capita cereal production, 1986-88 (kg/yr)	90	69	126	175
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	-1.7	-3.0	-1.3	-1.0
Maize production	6. Maize area harvested, 1986-88 (000 ha)	8	1	..	1,150
	7. Maize yield, 1986-88 (t/ha)	..	..	..	3.3
	8. Maize production, 1986-88 (000 t)	..	..	..	3,763
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	..	..	..	0.4
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	..	..	..	-0.2
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	..	..	..	1.7
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	..	..	..	2.3
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	..	..	..	2.1
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	..	..	..	2.1
	15. Estimated percentage white maize, 1988-89 (%)	..	..	..	..
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	0	0	..	10
	17. Average yield of all cereals, 1986-88 (t/ha)	0.8	0.7	0.9	1.7
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	-0.8	4.8	0.8	0.7
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	2.2	3.0	1.5	1.9
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	955	203	219	3,405
	21. Net imports of maize per capita, 1986-88 (kg/yr)	41	50	29	31
	22. Per capita total maize utilization, 1986-88 (kg/yr)	41	50	29	66
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	21.8	11.8	18.3	0.4
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	21.0	25.8	10.5	3.3
	25. Percentage food use of maize, 1985-87 (%)	2	4	0	37
	26. Percentage feed use of maize, 1985-87 (%)	98	96	99	57
	27. Percentage other use of maize, 1985-87 (%)	0	1	1	7
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	..	..	..	52
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	..	..	..	41
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	..	..	..	7
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	..	..	..
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	36	18	23	61
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	5.1	7.0	7.0	5.4
Prices	34. Farm price of maize, 1988/89 (US$/t)	..	..	..	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	..	..	..	..
	36. Farm wage in kg of maize per day, 1988/89	..	..	..	..

Data unavailable or incomplete.

		Producers	
		Afghanistan	Turkey
General indicators	1. Estimated population, 1989 (million)	..	54.7
	2. Estimated growth rate of population, 1987-2000 (%/yr)	..	1.9
	3. Per capita income, 1988 (US$)	..	1.280
	4. Per capita cereal production, 1986-88 (kg/yr)	296	567
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	0.5	0.6
Maize production	6. Maize area harvested, 1986-88 (000 ha)	454	543
	7. Maize yield, 1986-88 (t/ha)	1.7	4.1
	8. Maize production, 1986-88 (000 t)	778	2,233
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	-0.4	-0.8
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	-0.3	-0.9
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	1.2	3.2
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	0.4	5.7
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	0.7	2.3
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	0.2	4.7
	15. Estimated percentage white maize, 1988-89 (%)	..	10
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	14	4
	17. Average yield of all cereals, 1986-88 (t/ha)	1.3	2.2
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	1.9	2.3
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	0.2	2.8
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	..	149
	21. Net imports of maize per capita, 1986-88 (kg/yr)	..	3
	22. Per capita total maize utilization, 1986-88 (kg/yr)	53	45
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	-1.6	-0.3
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	0.6	3.0
	25. Percentage food use of maize, 1985-87 (%)	86	30
	26. Percentage feed use of maize, 1985-87 (%)	10	59
	27. Percentage other use of maize, 1985-87 (%)	4	11
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	..	54
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	..	13
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	..	33
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	180
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	11	60
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	9.7	8.8
Key prices	34. Farm price of maize, 1988/89 (US$/t)	..	122
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	..	3.9
	36. Farm wage in kg of maize per day, 1988/89	..	29

.. Data unavailable or incomplete.

		Iran	Iraq	Jordan	Saudi Arabia	Syria	Regional total or average
		Consumers					
General indicators	1. Estimated population, 1989 (million)	54.7	18.3	3.1	13.6	12.1	190.7
	2. Estimated growth rate of population, 1987-2000 (%/yr)	3.0	3.4	2.8	3.8	3.7	2.5
	3. Per capita income, 1988 (US$)	..	..	1,500	6,170	1,670	2,513
	4. Per capita cereal production, 1986-88 (kg/yr)	241	130	38	232	311	311
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	-0.2	-1.6	-5.2	17.4	0.1	0.1
Maize production	6. Maize area harvested, 1986-88 (000 ha)	47	30	<1	2	44	1,169
	7. Maize yield, 1986-88 (t/ha)	1.2	2.7	..	..	1.7	2.8
	8. Maize production, 1986-88 (000 t)	58	80	..	..	74	3,297
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	3.3	17.7	..	..	10.6	-0.2
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	3.5	5.1	..	..	8.4	-0.1
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	2.2	7.3	..	..	4.8	2.3
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	-2.2	-0.7	..	..	-1.3	3.3
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	5.6	26.4	..	..	15.9	2.1
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	1.2	4.4	..	..	7.0	3.2
	15. Estimated percentage white maize, 1988-89 (%)	0	..	..	..	10	10
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	<1	1	<1	<1	2	3
	17. Average yield of all cereals, 1986-88 (t/ha)	1.3	0.9	0.9	4.1	1.2	1.7
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	1.6	0.7	-2.7	-5.6	-1.0	1.6
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	1.8	0.3	2.8	16.6	3.0	2.4
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	828	473	229	446	111	2,631
	21. Net imports of maize per capita, 1986-88 (kg/yr)	16	28	78	35	10	15
	22. Per capita total maize utilization, 1986-88 (kg/yr)	17	32	78	36	16	33
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	17.2	25.3	6.5	7.6	11.0	0.5
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	8.4	17.5	11.2	11.2	12.1	4.1
	25. Percentage food use of maize, 1985-87 (%)	2	1	0	1	2	25
	26. Percentage feed use of maize, 1985-87 (%)	85	98	98	96	93	68
	27. Percentage other use of maize, 1985-87 (%)	13	2	2	3	4	8
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	0	..	..	..	0	44
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	0	..	..	..	12	12
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	100	..	..	..	88	44
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	..	..	..	200	182
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	61	35	30	350	44	55
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	15.6	15.7	9.1	29.8	12.3	11.2
Key prices	34. Farm price of maize, 1988/89 (US$/t)	80	..	..	..	500	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	0.3	..	..	..	1.0	..
	36. Farm wage in kg of maize per day, 1988/89	31	..	..	..	7	..

Data unavailable or incomplete.

South Asia

Section	Indicator	India	Myanmar	Nepal	Pakistan	Regional total or average
General indicators	1. Estimated population, 1989 (million)	834.2	40.8	18.7	118.8	1,143.5
	2. Estimated growth rate of population, 1987-2000 (%/yr)	1.8	2.2	2.5	3.3	2.0
	3. Per capita income, 1988 (US$)	330	..	170	350	315
	4. Per capita cereal production, 1986-88 (kg/yr)	206	368	263	174	211
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	0.6	2.1	-0.8	-0.3	0.5
Maize production	6. Maize area harvested, 1986-88 (000 ha)	5,788	152	675	848	7,553
	7. Maize yield, 1986-88 (t/ha)	1.2	1.7	1.4	1.3	1.3
	8. Maize production, 1986-88 (000 t)	7,074	256	947	1,123	9,524
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	2.0	-1.8	0.2	2.0	1.9
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	-0.2	6.9	3.3	2.6	0.4
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	0.5	3.2	-0.9	1.5	0.4
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	1.7	6.7	-1.9	0.4	1.4
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	2.5	1.3	-0.7	3.5	2.2
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	1.5	14.1	1.3	3.0	1.8
	15. Estimated percentage white maize, 1988-89 (%)	15	..	..	75	22
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	6	3	24	8	6
	17. Average yield of all cereals, 1986-88 (t/ha)	1.6	2.8	1.7	1.7	1.7
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	2.5	1.2	-0.6	4.4	2.2
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	2.7	4.5	-0.3	1.6	2.6
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	108	-14	3	0	116
	21. Net imports of maize per capita, 1986-88 (kg/yr)	0	0	0	0	0
	22. Per capita total maize utilization, 1986-88 (kg/yr)	9	6	53	10	9
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	0.0	1.0	-2.9	0.7	-0.3
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	-0.6	12.2	-1.3	-0.3	-0.5
	25. Percentage food use of maize, 1985-87 (%)	85	92	83	63	83
	26. Percentage feed use of maize, 1985-87 (%)	2	2	1	17	3
	27. Percentage other use of maize, 1985-87 (%)	14	6	16	19	14
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	38	66	90	74	47
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	49	34	10	23	42
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	14	0	0	3	11
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	62	..	..	80	64
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	57	21	21	86	59
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	10.8	15.3	13.5	11.7	10.8
Key prices	34. Farm price of maize, 1988/89 (US$/t)	163	..	..	125	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	2.1	..	..	2.6	..
	36. Farm wage in kg of maize per day, 1988/89	7	..	..	13	..

.. Data unavailable or incomplete.

		Producers				
		Indonesia	Kampuchea	Philippines	Thailand	Vietnam
General indicators	1. Estimated population, 1989 (million)	178.1	..	60.6	55.0	65.9
	2. Estimated growth rate of population, 1987-2000 (%/yr)	1.7	..	1.9	1.5	2.6
	3. Per capita income, 1988 (US$)	430	..	630	1000	..
	4. Per capita cereal production, 1986-88 (kg/yr)	270	280	227	441	256
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	3.2	3.2	0.5	1.0	0.9
Maize production	6. Maize area harvested, 1986-88 (000 ha)	3,045	35	3,674	1,708	402
	7. Maize yield, 1986-88 (t/ha)	2.0	2.8	1.2	2.4	1.4
	8. Maize production, 1986-88 (000 t)	5,960	98	4,266	4,085	570
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	-1.6	-5.8	3.9	7.9	1.0
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	1.0	-4.9	1.3	4.2	2.6
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	1.5	-1.4	2.2	1.1	0.3
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	4.5	7.7	2.5	1.1	2.1
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	-0.1	-7.1	6.2	9.1	1.3
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	5.5	2.5	3.9	5.4	4.8
	15. Estimated percentage white maize, 1988-89 (%)	41	..	64	0	..
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	23	2	52	15	7
	17. Average yield of all cereals, 1986-88 (t/ha)	3.6	1.3	1.9	2.1	2.6
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	3.8	1.3	2.4	0.1	0.8
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	3.9	0.1	2.9	1.1	2.2
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	99	..	27	-2,273	-32
	21. Net imports of maize per capita, 1986-88 (kg/yr)	1	..	0	-43	-1
	22. Per capita total maize utilization, 1986-88 (kg/yr)	35	13	74	34	9
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	-2.6	4.2	3.6	20.1	-0.2
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	3.7	1.7	1.1	9.3	-0.7
	25. Percentage food use of maize, 1985-87 (%)	92	72	45	12	82
	26. Percentage feed use of maize, 1985-87 (%)	2	9	46	77	12
	27. Percentage other use of maize, 1985-87 (%)	6	20	9	11	7
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	70	..	86	1	62
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	27	..	9	84	38
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	3	..	5	15	0
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	43	..	20	9	..
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	98	..	43	24	62
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	13.3	..	2.5	9.1	1.2
Key prices	34. Farm price of maize, 1988/89 (US$/t)	90	..	164	92	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	2.2	..	2.9	7.9	..
	36. Farm wage in kg of maize per day, 1988/89	7	..	10	17	..

. Data unavailable or incomplete.

		Consumers			Regional total or average
		Hong Kong	Malaysia	Singapore	
General indicators	1. Estimated population, 1989 (million)	5.8	16.9	2.7	404.1
	2. Estimated growth rate of population, 1987-2000 (%/yr)	1.0	2.2	0.8	1.8
	3. Per capita income, 1988 (US$)	9,230	1,870	9,100	867
	4. Per capita cereal production, 1986-88 (kg/yr)	0	107	..	268
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	-41.7	-3.6	..	1.7
Maize production	6. Maize area harvested, 1986-88 (000 ha)	..	16	..	8,917
	7. Maize yield, 1986-88 (t/ha)	..	..	..	1.7
	8. Maize production, 1986-88 (000 t)	..	..	..	15,054
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	..	..	..	1.6
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	..	..	..	1.7
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	..	..	..	1.8
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	..	..	..	3.1
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	..	..	..	3.5
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	..	..	..	4.9
	15. Estimated percentage white maize, 1988-89 (%)	..	..	..	34
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	..	3	..	22
	17. Average yield of all cereals, 1986-88 (t/ha)	1.6	2.7	..	2.6
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	0.5	2.3	..	2.1
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	0.4	-0.1	..	2.6
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	154	1,277	251	-465
	21. Net imports of maize per capita, 1986-88 (kg/yr)	27	79	96	-1
	22. Per capita total maize utilization, 1986-88 (kg/yr)	27	81	96	37
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	5.7	7.2	2.7	0.8
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	-2.1	10.8	1.5	3.5
	25. Percentage food use of maize, 1985-87 (%)	17	4	6	57
	26. Percentage feed use of maize, 1985-87 (%)	77	93	89	36
	27. Percentage other use of maize, 1985-87 (%)	6	3	5	7
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	..	..	..	61
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	..	..	..	32
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	..	..	..	6
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	..	..	26
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	..	157	1,300	65
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	..	7.6	10.9	7.8
Key prices	34. Farm price of maize, 1988/89 (US$/t)	..	..	..	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	..	..	..	..
	36. Farm wage in kg of maize per day, 1988/89	..	..	..	..

.. Data unavailable or incomplete.

		Producers		Consumers		Regional total or average
		China	Korea D.P.R.	Korea Republic	Taiwan	
General indicators	1. Estimated population, 1989 (million)	1,095.3	22.4	43.1	..	1,182.6
	2. Estimated growth rate of population, 1987-2000 (%/yr)	1.3	2.1	1.0	..	1.3
	3. Per capita income, 1988 (US$)	330	..	3,530	..	451
	4. Per capita cereal production, 1986-88 (kg/yr)	330	539	208	148	327
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	2.2	1.9	-1.2	-2.9	2.0
Maize production	6. Maize area harvested, 1986-88 (000 ha)	19,682	448	24	79	20,233
	7. Maize yield, 1986-88 (t/ha)	3.8	6.4	..	3.8	3.9
	8. Maize production, 1986-88 (000 t)	74,725	2,867	..	301	78,009
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	1.7	2.2	..	6.5	1.7
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	0.4	2.6	..	5.4	0.4
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	4.8	1.1	..	2.5	4.7
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	4.0	2.0	..	2.9	3.9
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	6.6	3.4	..	9.1	6.4
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	4.3	4.6	..	8.5	4.4
	15. Estimated percentage white maize, 1988-89 (%)	20	..	..	0	20
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	22	18	2	13	21
	17. Average yield of all cereals, 1986-88 (t/ha)	3.9	4.6	5.9	4.7	4.0
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	3.7	2.1	3.5	1.1	3.6
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	4.4	2.1	2.8	1.3	4.2
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	-3,745	0	4,429	3,745	4,428
	21. Net imports of maize per capita, 1986-88 (kg/yr)	-4	0	105	191	4
	22. Per capita total maize utilization, 1986-88 (kg/yr)	67	134	108	207	72
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	4.0	0.0	28.4	30.0	4.3
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	2.4	2.7	14.0	5.9	2.9
	25. Percentage food use of maize, 1985-87 (%)	29	8	2	3	25
	26. Percentage feed use of maize, 1985-87 (%)	64	72	82	95	67
	27. Percentage other use of maize, 1985-87 (%)	7	21	15	2	8
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	26	5	..	5	26
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	0	0	..	8	0
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	73	95	..	86	74
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	350	..	..	..	350
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	174	..	385	..	178
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	9.5	..	2.9	..	8.9
prices	34. Farm price of maize, 1988/89 (US$/t)	108	..	..	357	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	2.8	..	..	0.9	..
	36. Farm wage in kg of maize per day, 1988/89	7	..	..	35	..

.. Data unavailable or incomplete.

		Producers						
		Costa Rica	El Salvador	Guatemala	Haiti	Honduras	Mexico	Nicaragua
General indicators	1. Estimated population, 1989 (million)	2.9	5.1	8.9	6.4	5.0	86.5	3.7
	2. Estimated growth rate of population, 1987-2000 (%/yr)	2.0	2.1	2.8	1.9	2.9	1.9	3.0
	3. Per capita income, 1988 (US$)	1,760	950	880	360	850	1,820	..
	4. Per capita cereal production, 1986-88 (kg/yr)	112	139	166	65	120	272	154
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	-0.1	0.1	0.0	-2.1	-1.6	1.1	1.3
Maize production	6. Maize area harvested, 1986-88 (000 ha)	72	267	729	170	327	6,668	182
	7. Maize yield, 1986-88 (t/ha)	1.6	2.0	1.6	1.0	1.5	1.7	1.4
	8. Maize production, 1986-88 (000 t)	113	530	1,195	175	477	11,632	264
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	-0.9	1.8	-1.4	-0.8	2.0	-0.4	2.0
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	2.8	1.2	1.6	-1.1	-0.6	-0.2	-2.9
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	1.9	3.5	4.5	-1.2	-0.4	1.1	-0.2
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	1.0	1.6	0.9	0.8	2.8	3.5	4.6
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	1.0	5.4	3.1	-1.9	1.6	0.7	1.8
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	3.8	2.8	2.6	-0.3	2.1	3.4	1.6
	15. Estimated percentage white maize, 1988-89 (%)	98	100	..	..	99	85	..
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	53	66	86	49	86	67	62
	17. Average yield of all cereals, 1986-88 (t/ha)	2.3	1.7	1.7	1.1	1.5	2.3	1.8
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	2.6	2.8	4.5	0.3	-0.7	2.7	0.5
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	2.6	1.1	1.1	0.2	2.9	3.0	5.5
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	74	43	61	10	22	2,964	25
	21. Net imports of maize per capita, 1986-88 (kg/yr)	27	9	7	2	5	36	7
	22. Per capita total maize utilization, 1986-88 (kg/yr)	67	116	149	30	107	176	82
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	-0.6	1.1	0.5	-3.7	0.2	-0.6	-1.1
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	2.6	1.6	-0.4	-1.6	-1.4	1.1	-1.2
	25. Percentage food use of maize, 1985-87 (%)	63	79	66	83	76	80	83
	26. Percentage feed use of maize, 1985-87 (%)	32	16	25	8	14	9	6
	27. Percentage other use of maize, 1985-87 (%)	5	5	9	9	10	12	11
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	85	35	40	99	85	74	83
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	10	0	24	1	10	11	8
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	5	65	36	0	5	15	9
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	..	..	..	..	100	..
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	162	91	62	2	22	74	54
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	3.0	-0.9	4.7	11.6	2.2	7.5	5.9
Key prices	34. Farm price of maize, 1988/89 (US$/t)	205	196	..	..	150	158	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	3.0	3.1	..	..	2.3	1.6	..
	36. Farm wage in kg of maize per day, 1988/89	25	15	..	..	18	23	..

.. Data unavailable or incomplete.

		Consumers				Regional total or average
		Cuba	Dominican Republic	Jamaica	Panama	
General indicators	1. Estimated population, 1989 (million)	10.2	7.0	2.5	2.3	144.2
	2. Estimated growth rate of population, 1987-2000 (%/yr)	0.8	1.8	0.8	0.5	1.9
	3. Per capita income, 1988 (US$)	..	680	1,080	..	1,570
	4. Per capita cereal production, 1986-88 (kg/yr)	60	84	3	130	202
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	1.0	2.7	-4.3	-0.3	1.1
Maize production	6. Maize area harvested, 1986-88 (000 ha)	77	34	4	87	8,634
	7. Maize yield, 1986-88 (t/ha)	1.2	1.5	..	1.1	1.7
	8. Maize production, 1986-88 (000 t)	95	50	..	97	14,663
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	-1.2	0.3	..	-2.2	-0.3
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	-1.0	2.9	..	0.7	-0.1
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	1.3	1.8	..	0.3	1.3
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	1.2	-1.9	..	2.5	3.2
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	0.1	2.1	..	-1.9	1.0
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	0.2	0.9	..	3.2	3.1
	15. Estimated percentage white maize, 1988-89 (%)	..	0	..	0	85
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	33	21	83	48	67
	17. Average yield of all cereals, 1986-88 (t/ha)	2.6	3.5	1.5	1.6	2.2
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	4.7	2.9	4.1	2.3	2.7
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	2.5	2.4	-0.3	2.3	2.8
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	481	320	154	31	4,346
	21. Net imports of maize per capita, 1986-88 (kg/yr)	48	48	64	14	31
	22. Per capita total maize utilization, 1986-88 (kg/yr)	57	55	66	56	137
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	3.3	8.1	12.8	-2.9	0.0
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	1.6	6.0	0.6	1.6	1.1
	25. Percentage food use of maize, 1985-87 (%)	0	12	17	38	74
	26. Percentage feed use of maize, 1985-87 (%)	95	85	75	58	15
	27. Percentage other use of maize, 1985-87 (%)	5	3	8	4	11
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	80	85	..	80	72
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	20	15	..	6	11
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	0	0	..	14	17
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	79	..	199	101
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	..	41	51	62	68
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	..	1.4	-3.3	2.9	6.0
Key prices	34. Farm price of maize, 1988/89 (US$/t)	..	183	..	209	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	..	2.8	..	1.3	..
	36. Farm wage in kg of maize per day, 1988/89	..	13	..	22	..

.. Data unavailable or incomplete.

Andean Region, South America

		Producers					Regional total or average
		Bolivia	Colombia	Ecuador	Peru	Venezuela	
General indicators	1. Estimated population, 1989 (million)	7.1	31.1	10.4	21.7	19.2	91.0
	2. Estimated growth rate of population, 1987-2000 (%/yr)	2.7	1.7	2.2	2.1	2.2	2.0
	3. Per capita income, 1988 (US$)	570	1,240	1,080	..	3,170	1,676
	4. Per capita cereal production, 1986-88 (kg/yr)	120	108	97	105	130	116
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	1.2	-0.6	-0.2	0.4	3.5	0.6
Maize production	6. Maize area harvested, 1986-88 (000 ha)	267	617	413	440	659	2,399
	7. Maize yield, 1986-88 (t/ha)	1.7	1.4	1.0	2.0	1.9	1.6
	8. Maize production, 1986-88 (000 t)	444	843	399	891	1,240	3,820
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	0.5	-2.4	0.0	0.8	-0.1	-0.7
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	2.5	0.1	2.4	0.9	1.9	1.3
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	1.0	1.7	4.0	1.4	1.3	1.7
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	1.8	0.5	1.2	1.2	3.5	1.6
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	1.4	-0.7	4.0	2.3	1.1	1.1
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	4.3	0.6	3.7	2.1	5.5	3.0
	15. Estimated percentage white maize, 1988-89 (%)	0	65	20	23	77	50
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	44	47	61	50	56	50
	17. Average yield of all cereals, 1986-88 (t/ha)	1.3	2.5	1.4	2.5	2.0	2.1
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	1.5	4.9	3.3	1.7	2.6	3.1
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	1.5	1.0	1.4	2.9	2.1	1.5
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	0	25	0	446	0	489
	21. Net imports of maize per capita, 1986-88 (kg/yr)	0	1	0	21	0	6
	22. Per capita total maize utilization, 1986-88 (kg/yr)	66	29	40	64	68	49
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	-1.0	-2.7	0.8	1.1	1.1	-0.2
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	1.5	-1.8	0.9	1.0	1.0	0.4
	25. Percentage food use of maize, 1985-87 (%)	55	78	74	43	61	60
	26. Percentage feed use of maize, 1985-87 (%)	35	12	15	47	30	30
	27. Percentage other use of maize, 1985-87 (%)	10	10	10	10	9	10
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	76	87	51	58	0	51
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	21	5	39	18	9	16
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	3	8	10	24	91	33
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	71	60	80	220	119
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	2	77	41	31	140	62
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	6.8	6.4	7.3	0.3	14.1	7.[illegible]
Key prices	34. Farm price of maize, 1988/89 (US$/t)	152	184	127	324	103	
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	1.7	1.4	3.2	0.5	0.4	
	36. Farm wage in kg of maize per day, 1988/89	18	16	7	7	17	

.. Data unavailable or incomplete.

		Producers					Regional total or average
		Argentina	Brazil	Chile	Paraguay	Uruguay	
General indicators	1. Estimated population, 1989 (million)	31.9	147.0	12.9	4.1	3.1	199.1
	2. Estimated growth rate of population, 1987-2000 (%/yr)	1.1	1.8	1.4	2.7	0.7	1.7
	3. Per capita income, 1988 (US$)	2,640	2,280	1,510	1,180	2,470	2,268
	4. Per capita cereal production, 1986-88 (kg/yr)	759	292	221	325	345	365
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	-0.5	0.8	2.7	6.7	-0.2	0.2
Maize production	6. Maize area harvested, 1986-88 (000 ha)	2,856	13,041	94	522	79	16,592
	7. Maize yield, 1986-88 (t/ha)	3.6	1.8	7.1	1.7	1.4	2.2
	8. Maize production, 1986-88 (000 t)	10,183	24,012	666	890	108	35,859
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	0.4	2.6	1.4	5.2	-1.9	2.1
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	-0.3	1.3	0.9	7.1	-6.7	1.1
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	3.5	1.6	1.6	0.8	4.8	2.0
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	2.4	1.6	6.4	2.0	2.0	1.7
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	3.9	4.3	3.1	6.1	2.8	4.2
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	2.1	2.9	7.4	9.3	-4.9	2.8
	15. Estimated percentage white maize, 1988-89 (%)	..	0	..	30	..	2
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	30	57	11	70	16	48
	17. Average yield of all cereals, 1986-88 (t/ha)	2.5	1.8	3.4	1.7	2.1	2.0
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	2.4	0.5	0.7	0.9	2.7	1.2
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	1.9	2.1	5.4	1.7	4.5	2.0
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	-5,209	1,108	133	0	40	-3,928
	21. Net imports of maize per capita, 1986-88 (kg/yr)	-167	8	11	0	13	-20
	22. Per capita total maize utilization, 1986-88 (kg/yr)	160	178	64	227	48	166
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	3.0	1.4	2.8	3.5	1.0	1.8
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	0.3	1.5	4.5	6.0	-3.3	1.5
	25. Percentage food use of maize, 1985-87 (%)	2	14	15	30	28	13
	26. Percentage feed use of maize, 1985-87 (%)	89	75	78	52	63	77
	27. Percentage other use of maize, 1985-87 (%)	8	11	7	19	9	11
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	0	30	5	80	60	29
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	30	7	10	5	30	10
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	70	63	85	15	10	61
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	50	..	..	..	50
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	4	51	40	6	47	36
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	3.2	6.6	1.5	-3.3	-0.2	6.1
prices	34. Farm price of maize, 1988/89 (US$/t)	99	132	136	90	..	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	5.1	6.0	4.4	..	..	..
	36. Farm wage in kg of maize per day, 1988/89	..	14	..	46	..	..

.. Data unavailable or incomplete.

Eastern Europe and USSR

		Producers			
		Bulgaria	Czecho-slovakia	Hungary	Romania
General indicators	1. Estimated population, 1989 (million)	9.0	15.7	10.6	23.1
	2. Estimated growth rate of population, 1987-2000 (%/yr)	0.2	0.3	-0.2	0.5
	3. Per capita income, 1988 (US$)	..	..	2,460	..
	4. Per capita cereal production, 1986-88 (kg/yr)	878	737	1,354	1,354
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	-0.1	1.2	1.8	4.4
Maize production	6. Maize area harvested, 1986-88 (000 ha)	522	201	1,146	3,023
	7. Maize yield, 1986-88 (t/ha)	4.0	5.2	6.0	6.4
	8 Maize production, 1986-88 (000 t)	2,110	1,049	6,841	19,345
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	0.4	-1.1	1.0	-0.3
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	-2.2	2.5	-2.0	-0.4
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	2.9	4.3	3.9	3.7
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	0.7	1.5	3.0	6.4
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	3.3	3.1	4.9	3.4
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	-1.5	4.1	1.0	6.0
	15. Estimated percentage white maize, 1988-89 (%)	..	0	0	..
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	25	8	40	49
	17. Average yield of all cereals, 1986-88 (t/ha)	3.8	4.6	5.0	5.0
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	4.2	4.4	5.2	4.0
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	0.9	2.3	2.7	4.9
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	565	147	-230	22
	21. Net imports of maize per capita, 1986-88 (kg/yr)	63	9	-22	1
	22. Per capita total maize utilization, 1986-88 (kg/yr)	298	77	623	845
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	3.3	4.0	3.3	3.6
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	-0.5	-0.4	1.5	5.2
	25. Percentage food use of maize, 1985-87 (%)	1	3	0	8
	26. Percentage feed use of maize, 1985-87 (%)	80	91	96	69
	27. Percentage other use of maize, 1985-87 (%)	19	6	4	23
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	..	0	0	0
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	..	0	0	0
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	..	100	100	100
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	400	380	..
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	..	..	262	130
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	..	..	3.5	5.4
Key prices	34. Farm price of maize, 1988/89 (US$/t)	..	65	104	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	..	1.7	3.5	..
	36. Farm wage in kg of maize per day, 1988/89	..	65	64	..

.. Data unavailable or incomplete.

		Producers		Region total or average
		USSR	Yugoslavia	
General indicators	1. Estimated population, 1989 (million)	288.0	23.7	428.0
	2. Estimated growth rate of population, 1987-2000 (%/yr)	0.7	0.6	0.6
	3. Per capita income, 1988 (US$)	..	2,680	..
	4. Per capita cereal production, 1986-88 (kg/yr)	694	690	746
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	-0.9	-0.2	-0.1
Maize production	6. Maize area harvested, 1986-88 (000 ha)	4,409	2,285	11,700
	7. Maize yield, 1986-88 (t/ha)	3.3	4.2	4.6
	8. Maize production, 1986-88 (000 t)	14,439	9,695	53,947
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	-3.5	-0.5	-1.3
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	2.0	-0.1	0.3
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	3.1	3.7	3.6
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	0.5	1.2	2.5
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	-0.5	3.2	2.3
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	2.6	1.1	2.8
	15. Estimated percentage white maize, 1988-89 (%)	..	0	..
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	4	55	8
	17. Average yield of all cereals, 1986-88 (t/ha)	1.8	3.9	2.3
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	3.2	4.1	3.4
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	0.9	1.6	1.5
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	9,022	-875	9,460
	21. Net imports of maize per capita, 1986-88 (kg/yr)	32	-37	22
	22. Per capita total maize utilization, 1986-88 (kg/yr)	83	377	150
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	2.9	2.1	3.3
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	3.1	-0.2	2.0
	25. Percentage food use of maize, 1985-87 (%)	0	6	4
	26. Percentage feed use of maize, 1985-87 (%)	62	77	72
	27. Percentage other use of maize, 1985-87 (%)	38	17	25
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	..	..	..
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	..	..	..
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	..	..	..
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	323	..
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	..	..	..
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	..	..	..
Key prices	34. Farm price of maize, 1988/89 (US$/t)	..	219	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	..	2.3	..
	36. Farm wage in kg of maize per day, 1988/89	..	16	..

Data unavailable or incomplete.

		Producers				
		Austria	Canada	France	West Germany	Greece
General indicators	1. Estimated population, 1989 (million)	7.6	26.1	56.1	61.2	10.0
	2. Estimated growth rate of population, 1987-2000 (%/yr)	-0.1	0.8	0.4	-0.2	0.2
	3. Per capita income, 1988 (US$)	15,560	16,760	16,080	18,530	4,790
	4. Per capita cereal production, 1986-88 (kg/yr)	679	1,871	956	417	512
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	2.6	0.8	2.8	1.9	2.3
Maize production	6. Maize area harvested, 1986-88 (000 ha)	208	992	1,854	193	231
	7. Maize yield, 1986-88 (t/ha)	8.2	6.2	6.9	7.0	8.7
	8. Maize production, 1986-88 (000 t)	1,708	6,098	12,702	1,351	2,011
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	10.3	8.6	6.2	15.8	-1.4
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	2.8	4.6	0.4	5.7	5.0
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	4.2	0.8	3.0	3.2	8.2
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	2.1	1.2	3.1	2.2	7.9
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	14.9	9.5	9.3	19.6	6.7
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	5.0	5.9	3.5	8.0	13.3
	15. Estimated percentage white maize, 1988-89 (%)	0	1	0	..	0
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	21	5	20	4	16
	17. Average yield of all cereals, 1986-88 (t/ha)	5.1	2.3	5.7	5.4	3.5
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	4.0	1.6	3.0	2.4	3.8
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	2.3	0.6	3.5	2.7	3.5
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	-225	196	-5,816	1,107	-46
	21. Net imports of maize per capita, 1986-88 (kg/yr)	-30	8	-105	18	-5
	22. Per capita total maize utilization, 1986-88 (kg/yr)	196	245	124	40	197
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	4.7	6.1	6.3	5.8	10.7
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	3.8	3.1	0.3	-3.2	3.1
	25. Percentage food use of maize, 1985-87 (%)	1	17	..	..	..
	26. Percentage feed use of maize, 1985-87 (%)	94	82	..	..	..
	27. Percentage other use of maize, 1985-87 (%)	5	0	..	..	..
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	0	0	0	0	0
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	0	0	0	0	0
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	100	100	100	100	100
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)					
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	206	47	309	428	171
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	-1.0	5.8	1.5	0.0	4.4
Key prices	34. Farm price of maize, 1988/89 (US$/t)	255	120	192	..	193
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	5.2	3.4	1.4	..	1.3
	36. Farm wage in kg of maize per day, 1988/89	163	414	24	..	155

.. Data unavailable or incomplete.

		Producers			
		Italy	South Africa	Spain	United States
General indicators	1. Estimated population, 1989 (million)	57.4	34.5	39.2	248.0
	2. Estimated growth rate of population, 1987-2000 (%/yr)	-0.1	2.3	0.3	0.8
	3. Per capita income, 1988 (US$)	13,320	2,290	7,740	19,780
	4. Per capita cereal production, 1986-88 (kg/yr)	317	337	521	1,097
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	1.0	-2.6	3.3	0.7
Maize production	6. Maize area harvested, 1986-88 (000 ha)	820	3,886	541	25,162
	7. Maize yield, 1986-88 (t/ha)	7.5	1.9	6.5	6.8
	8. Maize production, 1986-88 (000 t)	6,161	7,450	3,519	171,399
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	-1.4	2.3	-0.1	1.6
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	-0.4	-3.1	0.8	-0.1
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	5.4	2.0	4.8	2.1
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	1.9	1.5	4.5	2.3
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	3.9	4.4	4.7	3.7
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	1.4	-1.7	5.4	2.2
	15. Estimated percentage white maize, 1988-89 (%)	2	51	..	1
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	17	57	7	42
	17. Average yield of all cereals, 1986-88 (t/ha)	3.9	1.6	2.6	4.4
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	3.1	2.4	3.3	1.9
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	1.8	0.8	3.6	2.3
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	984	-1,563	1,166	-38,060
	21. Net imports of maize per capita, 1986-88 (kg/yr)	17	-47	30	-156
	22. Per capita total maize utilization, 1986-88 (kg/yr)	125	178	120	547
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	2.0	1.5	6.9	1.3
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	-2.9	-1.8	-1.2	1.4
	25. Percentage food use of maize, 1985-87 (%)	..	52	..	2
	26. Percentage feed use of maize, 1985-87 (%)	..	44	..	79
	27. Percentage other use of maize, 1985-87 (%)	..	4	..	19
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	5	0	..	0
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	0	0	..	0
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	95	100	..	100
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	460	100	..	300
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	169	62	91	92
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	4.1	2.4	2.7	0.7
Key prices	34. Farm price of maize, 1988/89 (US$/t)	243	103	..	100
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	2.5	2.3	..	4.0
	36. Farm wage in kg of maize per day, 1988/89	200	16	..	426

.. Data unavailable or incomplete.

		Consumers				
		Belgium & Luxembourg	Japan	Netherlands	Portugal	United Kingdom
General indicators	1. Estimated population, 1989 (million)	10.2	123.1	14.8	10.3	57.3
	2. Estimated growth rate of population, 1987-2000 (%/yr)	0.0	0.4	0.3	0.1	0.1
	3. Per capita income, 1988 (US$)	14,550	21,040	14,530	3,670	12,800
	4. Per capita cereal production, 1986-88 (kg/yr)	216	121	82	155	392
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	1.2	-1.6	-0.4	-0.8	3.9
Maize production	6. Maize area harvested, 1986-88 (000 ha)	7	<1	<1	250	<1
	7. Maize yield, 1986-88 (t/ha)	..	..	..	2.6	..
	8. Maize production, 1986-88 (000 t)	..	..	..	648	..
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	..	..	..	-2.3	..
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	..	..	..	-3.7	..
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	..	..	..	1.4	..
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	..	..	..	5.5	..
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	..	..	..	-0.9	..
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	..	..	..	1.7	-22.7
	15. Estimated percentage white maize, 1988-89 (%)	..	..	..	20	..
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	2	0	0	25	0
	17. Average yield of all cereals, 1986-88 (t/ha)	5.9	5.7	6.6	1.6	5.7
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	1.3	2.6	1.6	2.5	1.0
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	3.1	0.1	3.1	3.1	3.3
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	1,063	15,904	1,848	837	1,417
	21. Net imports of maize per capita, 1986-88 (kg/yr)	104	130	126	82	25
	22. Per capita total maize utilization, 1986-88 (kg/yr)	109	130	126	145	25
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	6.0	7.8	2.7	8.0	-0.7
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	-0.9	5.0	-3.2	0.0	-7.8
	25. Percentage food use of maize, 1985-87 (%)	..	14	..	..	9
	26. Percentage feed use of maize, 1985-87 (%)	..	82	..	..	77
	27. Percentage other use of maize, 1985-87 (%)	..	3	..	..	14
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	..	1	0	75	..
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	..	2	0	0	..
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	..	97	100	25	..
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	..	..	..	170	..
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	528	427	770	98	380
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	-0.5	0.6	0.2	5.3	2.3
Key prices	34. Farm price of maize, 1988/89 (US$/t)	..	..	..	271	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	..	..	..	2.8	..
	36. Farm wage in kg of maize per day, 1988/89	..	..	..	31	..

.. Data unavailable or incomplete.

		Developing Countries	Developed Market Economies	Eastern Europe and USSR	World
General indicators	1. Estimated population, 1989 (million)	3,948.3	813.8	428.0	5,190.1
	2. Estimated growth rate of population, 1987-2000 (%/yr)	1.9	0.5	0.6	1.6
	3. Per capita income, 1988 (US$)	673	16,399	..	3,558
	4. Per capita cereal production, 1986-88 (kg/yr)	250	671	746	359
	5. Growth rate of per capita cereal production, 1973-77 to 1984-88 (%/yr)	1.0	1.2	-0.1	0.5
Maize production	6. Maize area harvested, 1986-88 (000 ha)	81,813	34,258	11,700	127,771
	7. Maize yield, 1986-88 (t/ha)	2.2	6.2	4.6	3.5
	8. Maize production, 1986-88 (000 t)	182,732	213,712	53,947	450,391
	9. Growth rate of maize area, 1962-66 to 1973-77 (%/yr)	1.3	1.8	-1.3	1.2
	10. Growth rate of maize area, 1973-77 to 1984-88 (%/yr)	0.8	-0.3	0.3	0.4
	11. Growth rate of maize yield, 1962-66 to 1973-77 (%/yr)	2.8	2.2	3.6	2.7
	12. Growth rate of maize yield, 1973-77 to 1984-88 (%/yr)	2.6	2.6	2.5	2.4
	13. Growth rate of maize production, 1962-66 to 1973-77 (%/yr)	4.1	4.1	2.3	3.9
	14. Growth rate of maize production, 1973-77 to 1984-88 (%/yr)	3.5	2.3	2.8	2.8
	15. Estimated percentage white maize, 1988-89 (%)	32	3	..	17
	16. Maize area as a percentage of total cereal area, 1986-88 (%)	19	24	8	18
	17. Average yield of all cereals, 1986-88 (t/ha)	2.3	3.7	2.3	2.6
	18. Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	2.5	1.9	3.4	2.5
	19. Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	2.8	2.0	1.5	2.3
Trade and utilization	20. Net imports of maize, 1986-88 (000 t)	11,066	-20,484	9,460	..
	21. Net imports of maize per capita, 1986-88 (kg/yr)	3	-25	22	..
	22. Per capita total maize utilization, 1986-88 (kg/yr)	51	240	150	90
	23. Growth rate of per capita maize utilization, 1962-66 to 1973-77 (%/yr)	2.0	2.3	3.3	1.8
	24. Growth rate of per capita maize utilization, 1973-77 to 1984-88 (%/yr)	1.8	1.2	2.0	1.0
	25. Percentage food use of maize, 1985-87 (%)	40	6	4	20
	26. Percentage feed use of maize, 1985-87 (%)	50	78	72	66
	27. Percentage other use of maize, 1985-87 (%)	10	16	25	14
Maize types and productivity factors	28. Area planted to unimproved local varieties as a percentage of total maize area, 1988 (%)	47	1	..	32
	29. Area planted to improved OPVs as a percentage of total maize area, 1988 (%)	14	0	..	10
	30. Area planted to hybrids as a percentage of total maize area, 1988 (%)	39	99	..	59
	31. Fertilizer applied to maize, 1988/89 (kg nutrients/ha)	144	285	..	194
	32. Fertilizer applied to all crops, 1986 (kg nutrients/ha)	62	114	..	83
	33. Growth rate of fertilizer applied to all crops, 1970 to 1986 (%/yr)	8.4	1.0	..	3.6
Key prices	34. Farm price of maize, 1988/89 (US$/t)	..	..	..	..
	35. Ratio of farm-level nitrogen price to maize price, 1988/89	..	..	..	..
	36. Farm wage in kg of maize per day, 1988/89	..	..	..	..

Data unavailable or incomplete.

Annex 1: Regions of the World (Delineated for This Study)

Developing Countries

Eastern and Southern Africa
Angola
Botswana
Burundi
Comoros
Djibouti
Ethiopia
Kenya
Lesotho
Madagascar
Malawi
Mauritius
Mozambique
Namibia
Rwanda
Seychelles
Somalia
Sudan
Swaziland
Tanzania
Uganda
Zambia
Zimbabwe

Western and Central Africa
Benin
Burkina Faso
Cameroon
Cape Verde
Central African Republic
Chad
Congo
Côte D'Ivoire
Equatorial Guinea
Gabon
Gambia
Ghana
Guinea
Guinea-Bissau
Liberia
Mali
Mauritania
Niger
Nigeria
Reunion
Sao Tome
Senegal
Sierra Leone
St. Helena
Togo
Zairc

North Africa
Algeria
Egypt
Libya
Morocco
Tunisia
Western Sahara

West Asia
Afghanistan
Bahrain
Cyprus
Iran
Iraq
Jordan
Kuwait
Lebanon
Oman
Qatar
Saudi Arabia
Syria
Turkey
United Arab Emirates
Yemen, North
Yemen, South

South Asia
Bangladesh
Bhutan
India
Maldives
Myanmar
Nepal
Pakistan
Sri Lanka

Southeast Asia and the Pacific
Brunei
Fiji
French Polynesia
Hong Kong
Indonesia
Kampuchea
Laos
Macau
Malaysia
New Caledonia
Papua New Guinea
Philippines
Samoa
Singapore
Solomon Islands
Thailand
Tonga
Vanuatu
Vietnam

East Asia
China
Korea, North
Korea, South
Mongolia
Taiwan

Mexico, Central America, and the Caribbean
Bahamas
Barbados
Belize
Costa Rica
Cuba
Dominican Republic
El Salvador
Grenada
Guadalupe
Guatemala
Haiti
Honduras
Jamaica
Martinique
Mexico
Montserrat
Netherlands Antilles
Nicaragua
Panama
Trinidad and Tobago

Andean Region
Bolivia
Colombia
Ecuador
French Guiana
Guyana
Peru
Surinam
Venezuela

Southern Cone, South America
Argentina
Brazil
Chile
Paraguay
Uruguay

Industrialized Countries

Eastern Europe and USSR
Albania
Bulgaria
Czechoslovakia
Germany, East
Hungary
Poland
Romania
USSR
Yugoslavia

Developed Market Economies
Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany, West
Greece
Greenland
Iceland
Ireland
Israel
Italy
Japan
Luxemburg
Malta
Netherlands
New Zealand
Norway
Portugal
South Africa
Spain
Sweden
Switzerland
United Kingdom
USA

Annex 2: Regions of Sub-Saharan Africa (Delineated for This Study)

Sahel
Burkina Faso
Cape Verde
Chad
Gambia
Mali
Mauritania
Niger
Senegal

Western and Central Africa
Benin
Côte D'Ivoire
Ghana
Guinea
Guinea-Bissau
Liberia
Nigeria
Sierra Leone
Togo
Burundi
Cameroon
Central African Republic
Congo
Equatorial Guinea
Gabon
Rwanda
Sao Tome
St. Helena
Zaire

Eastern Africa
Djibouti
Ethiopia
Kenya
Somalia
Sudan
Uganda

Southern Africa
Angola
Botswana
Comoros
Lesotho
Madagascar
Malawi
Mauritius
Mozambique
Namibia
Reunion
Seychelles
Swaziland
Tanzania
Zambia
Zimbabwe

References

Akobundu, I.O. 1987. *Weed Science: Principles and Practices*. Chichester, U.K.: John Wiley.

Amani, H.K.R., S.M. Kipunda, N.H.I. Lipumba, and B.J. Ndulu. 1989. Impact of market liberalisation on household food security in Tanzania. In G. Mudimu and R.H. Bernsten (eds.), *Household and National Food Security in Southern Africa*. Harare: University of Zimbabwe/Michigan State University Food Security Research Project, Department of Agricultural Economics and Extension, Harare. 29-43.

Anandajaysekeram, P., and J. Ransom. 1988. Maize production technology in Eastern Africa. Nairobi: CIMMYT. Mimeo.

Binswanger, H.P., and J. McIntire. 1987. Behavioral and material determinants of production relations in land abundant tropical agriculture. *Economic Development and Cultural Change* 36(1): 73-97.

Bruce, K., D. Byerlee, and G.O. Edmeades. 1980. *Maize in the Mampong-Sekodumasi Area of Ghana: Results of an Exploratory Survey.* CIMMYT Economics Program Working Paper. Mexico, D.F.: CIMMYT.

Buccola, S.T., and C. Sukume. 1989. Optimal grain pricing and storage policy: Application to Zimbabwe. *World Development* 16(3): 361-371.

Carr, S.J. 1989. *Technology for Small-Scale Farmers in Sub-Saharan Africa: Experience with Food Crop Production in Five Major Ecological Zones.* World Bank Technical Paper No. 109. Washington, D.C.: World Bank.

Christiansen, R.E., and L.A. Stackhouse. 1989. The privatization of agricultural trading in Malawi. *World Development* 17(5): 729-740.

CIMMYT. 1987. *1986 CIMMYT World Maize Facts and Trends: The Economics of Commercial Maize Seed Production in Developing Countries*. Mexico, D.F.

____________. 1989. *CIMMYT International Maize Testing Program: 1987 Final Report*. Mexico, D.F.

Dahniya, M.T., A.B. Gbani, M. Lahai, and P. Kormawa. 1986. Farming systems research in the Kamajei and Kowa chiefdoms, Moyamba District. Paper presented at the 15th Annual Conference of the Agricultural Society of Sierra Leone, 1-4 October, Makeni, Sierra Leone.

Delgado, C.L. 1985. Food-grain market integration in Northern Nigeria: Implications for sub-regional equity concerns. In *Agricultural Markets in the Semi-Arid Tropics: Proceedings of the International Workshop, 24-28 October, 1983*. Hyderabad: International Crops Research Institute for the Semi-Arid Tropics.

Delgado, C.L., and C.P.J. Miller. 1985. Changing food patterns in West Africa: Implications for policy research. *Food Policy* 10(1): 55-62.

Edmeades, G.O., J. Bolaños, H.R. Lafitte, S. Rajaram, W. Pfeiffer, and R.A. Fischer. 1988. Traditional approaches to breeding for drought resistance in cereals. Paper presented at the Symposium on Drought Resistance in Cereals: Theory and Practice, 28-30 November, Cairo, Egypt.

Eicher, C.K. 1989. *Sustainable Institutions for African Agricultural Development.* ISNAR Working Paper No. 19. The Hague: International Service for National Agricultural Research.

Food and Agricultural Organization. 1984. *Structure and Characteristics of the World White Maize Economy.* Report of the Committee on Commodity Problems, 22nd Session of the Intergovernmental Group on Grains, CCP:GR 84/5, Rome, 8-12 October. Rome: FAO.

____________. 1987. Computer printout. Rome: FAO Commodities and Trade Division.

____________. 1988. Tapes of population statistics. Rome: FAO.

____________. 1988. Tapes of production statistics. Rome: FAO.

____________. 1988. Tapes of trade statistics. Rome: FAO.

Hays, H.M., and J.H. McCoy. 1977. Food grain marketing in Northern Nigeria: Spatial and temporal performance. *Journal of Development Studies* 14(2): 182-92.

International Fertilizer Development Center. 1985. *Fertilizer Research Program for Africa: The Fate, Sources, and Management of Nitrogen and Phosphorus Fertilizers in Sub-Saharan Africa. Final Report on Phase 1 Activities, 1982-84*. Muscle Shoals, Alabama: IFDC.

International Institute of Tropical Agriculture. 1988. *IITA Strategic Plan: 1989-2000*. Ibadan: IITA.

Jones, W.O. 1984. Economic tasks for food marketing boards in tropical Africa. *Food Research Institute Studies* 19(2): 113-38.

Kang, B.T., and V. Balasubramanian. 1990. Long term fertilizer trials in Alfisols in West Africa. Paper presented at the International Soil Science Society Annual Meeting, August, Kyoto, Japan.

Kassam, A.H. 1976. Crops of West African Semi-Arid Tropics. Hyderabad: International Crops Research Institute for the Semi-Arid Tropics. Mimeo.

Kingsbury, D.S. 1989. An analysis of price and non-price barriers to agricultural marketing and trade in Southern Africa. Unpublished PhD thesis. East Lansing: Michi-

Low, A. 1988. Farm-household economics and the design and impact of biological research in Southern Africa. *Agricultural Administration and Extension* 29: 23-34.

Low, A., and S. Waddington. 1989. On-farm research for maize production technologies for smallholder farmers in southern Africa: Current achievements and future prospects. Paper presented at the 3rd Eastern and Southern Africa Regional Maize Workshop, 17-23 September, Nairobi, Kenya.

McIntire, J. 1986. Constraints to fertilizer use in sub-Saharan Africa. In A. Uzo Mokwunye and P.L.G. Vlek (eds.), *Management of Nitrogen and Phosphorus Fertilizers in Sub-Saharan Africa*. Proceedings of a symposium, March 1985, Lome, Togo. Dordrecht: Martinus Nijhoff.

Mihm, J., and B. Renfro. 1987. Management of maize insect and disease pests using host plant resistance: Successes and prospects. Paper presented at the 11th International Congress of Plant Protection, 4-9 October, Manila, Philippines.

Muir, K., and T. Takavarasha. 1989. Pan-territorial and pan-seasonal pricing for maize in Zimbabwe. In G. Mudimu and R.H. Bernsten (eds.), *Household and National Food Security in Southern Africa*. Harare: University of Zimbabwe/ Michigan State University Food Security Research Project, Department of Agricultural Economics and Extension, Harare. 103-124.

Muir-Leresche, K. 1985. Crop and wage policy in the light of Zimbabwe's development goals. Unpublished D Phil thesis. Harare: University of Zimbabwe.

Ndiaye, S., and A.J. Sofranko. 1988. Importance of labor in adoption of a modern farm input. *Rural Sociology* 53(4): 421-432.

Ouedraogo, I.S., and O. Ndoye. 1988. Guide de collecte des prix en Afrique du Sud du Sahara: Leçons tirées du Sénégal. Paper presented at the seminar, La politique agricole au Sénégal, 7-8 July 1988, Dakar, Senegal.

Pinckney, T.C., and A. Valdes. 1988. Short-run supply management and food security: Results from Pakistan and Kenya. *World Development* 16(9): 1025-1034.

Pingali, P., Y. Bigot, and H. Binswanger. 1987. *Agricultural Mechanization and the Evolution of Farming Systems in Sub-Saharan Africa*. Baltimore: Johns Hopkins Univrsity Press.

Rodríguez, M.S. 1989. Agronomic practices to minimize drought stress for sustainable maize production in the Sudan and northern Guinea savanna zones. Paper presented at the Semi-Arid Food Grain Research and Development (SAFGRAD) Project workshop, Appropriate Technologies for Developing Sustainable Food Production Systems in the Semi-Arid Regions of Sub-Saharan Africa, 11-14 April 1989, Ouagadougou, Burkina Faso.

Rohrbach, D. 1988. The growth of smallholder maize production in Zimbabwe: Causes and implications for food security. Unpublished PhD dissertation. East Lansing: Michigan State University.

Shepherd, A. 1989. Approaches to the privatization of fertilizer marketing in Africa. *Food Policy* 14(2): 143-154.

Sipula, K.F., J.T. Milimo, C. Mliwa, and D. Mendamenda. 1989. Agricultural policy and its effect on food security: The Zambian case. In G. Mudimu and R.H. Bernsten (eds.), *Household and National Food Security in Southern Africa*. Harare: University of Zimbabwe/ Michigan State University Food Security Research project, Department of Agricultural Economics and Extension, Harare. 63-75.

Smith, J., J. Mareck, J.N. Fajemisin, K.O. Makinde, and D.B. Oyewole. Spread of improved maize varieties in the cocoa belt of South West Nigeria. Ibadan: IITA. Mimeo. (Forthcoming.)

Southworth, V.R., W.O. Jones, and S.R. Pearson. 1979. Food crop marketing in Alebubu District, Ghana. *Food Research Institute Studies* 17(2): 157-195.

Tripp, R., K. Marfo, A.A. Dankyi, and M. Read. 1987. *Changing Maize Production Practices of Small-scale Farmers in the Brong-Ahafo Region, Ghana*. Mexico, DF: Ghana Grains Development Project.

Vernon, R., and J.M.H. Parker. 1983. Maize/weed competition experiments: Implications for tropical small-farm weed control research. *Experimental Agriculture*, 19 (4): 341-348.

Williams, S.B., and O.L. Oludimu. 1986. *Maize: A Study of Its Marketing Channels, Margins and Utilization in Ondo State*. Ile-Ife, Nigeria: University of Ife.

World Bank. 1989. *World Development Report 1989*. New York: Oxford University Press.

Yallou, C.G., A.T. Massan, J.H. Mareck, and G.K. Weber. 1989. Amelioration varietale du maïs au Benin. Cotonou: Direction de Recherche Agronomique. Mimeo.

Yudelman, M. 1964. *Africans on the Land*. London: Oxford University Press.

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