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Food Production in the African Sahel: Short-Term Relief, Long-Term Problems

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A Research Paper

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GI 87-10028
April 1987

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Food Production in the African Sahel: Short-Term Relief, Long-Term Problems [redacted] 25X1

A Research Paper

25X1 This paper was prepared by [redacted] Office of Global Issues, with contributions from the Office of African and Latin American Analysis, the Office of Near East and South Asian Analysis, and the Office of Information Resources. It was coordinated with the US Agency for International Development. [redacted] 25X1 25X1

Comments and queries are welcome and may be directed to the Chief, Strategic Resources Division [redacted] 25X1

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Food Production in the African Sahel: Short-Term Relief, Long-Term Problems [redacted]

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Summary

Information available as of 1 March 1987 was used in this report.

The roughly 100 million people who live in the African Sahel and the Horn of Africa are among the poorest in the world. The eight countries in the region—Mauritania, Mali, Burkina, Niger, Chad, Sudan, Ethiopia, and Somalia—have precarious economies and governments prone to political instability. The severe drought that covered portions of all eight countries during the first half of the 1980s dealt a heavy blow to the economic, social, demographic, and political fabric of the region and led to famine conditions and widespread loss of life. Recent improvements in rainfall have resulted in some relief from the worst immediate effects of the drought, but the longer term outlook for the region's food balance remains grim. [redacted]

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Rainfall remains the key factor that will determine the region's general well-being over the rest of the decade. Analysis of historical weather data indicates that weather patterns over the next five years are likely to fall within a clear range:

- The best bet is for rainfall to stabilize somewhat around recent levels.
- There is also a good chance that rainfall may continue the downward trend of the last 25 years.
- There is a small chance that the recent rains could indicate a return to a wet period like the early 1960s.

While there is some disagreement among climatologists on the trend in Africa's climate, the majority agree with our most likely projection that precipitation rates for the next few years will closely follow the trend of the early 1980s. [redacted]

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Given this climate outlook, our estimates indicate that prospects for improving food availability through domestic grain production are bleak. Unless weather conditions during 1986-90 come close to the best we examined—a highly unlikely event—per capita output of grain will most likely decline from the low 1981-85 levels, continuing a general trend of the last 25 years. Although there may be some modest gains in total grain production, they will be outstripped by the region's rapid population growth. [redacted]

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There is little chance, then, that the region can avoid increased grain import requirements. Most of those imports would have to be provided through various assistance programs, because the region already spends about one-fourth of its meager export earnings on grain imports. Annual regional needs by 1990 could run 50 percent or more above the 2.2 million

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metric tons per year average of 1981-85 just to maintain recent per capita consumption levels; the cost at world market prices would exceed $1 billion. In the best case we examined, four of the countries—Mauritania, Mali, Ethiopia, and Somalia—would still need substantial increases in grain imports just to keep per capita grain consumption stable. Even with the increases, Ethiopia and Mali would have no hope of meeting the minimum nutritional standard consumption levels established by the Food and Agriculture Organization (FAO) of the United Nations. In the other cases we examined, which are much more likely, all eight countries would need increased grain imports to maintain per capita consumption, and most increases would be substantial. [redacted] 25X1

This means that financial pressures will continue to be severe and conditions fostering political instability will probably intensify. The grain import bill is already so large—about $475 million annually during 1981-85—that it sharply limits the impact of foreign trade on economic development in the region. Moreover, continued food shortages and drought-induced crop failures are likely to force more migration into the already overcrowded cities and across international borders, encouraging both domestic unrest and the risk of conflict between countries in the region. [redacted] 25X1

The United States and the rest of the West will face large and probably rising requests for food aid to the region as 1990 approaches. If rainfall levels fall in the range we believe is likely, there may be little the countries themselves can do in the short run to avoid a return to famine conditions, at least in regions that are on the fringe of adequate rainfall and are difficult to reach with limited grain surpluses possibly available from other parts of a given country. In fact, the primitive transportation and communication infrastructure in the region makes it likely that pockets of serious food shortages will arise and go undetected by authorities for some time, sharply raising the risk of starvation. Western logistic aid, therefore, will also be a continuing need in the region. [redacted] 25X1

The only longer term hope is policy adjustments needed to induce improvement in the primitive level of the region's agrotechnology, which would raise regional grain production and limit import needs. The West is in an excellent position to provide this agrotechnical assistance, despite the vagaries of climate and limited arable land available. Much technology is readily available or could be easily tailored to the conditions of the region. Such a program would also sharply contrast with Moscow's failure to provide such agricultural assistance because of its own limitations in the agricultural arena. Western pressure on local governments to make the policy environment more supportive of improved agrotechnology would be a critical adjunct to such an aid program. [redacted] 25X1

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Figure 1. Major Grain-Producing Area

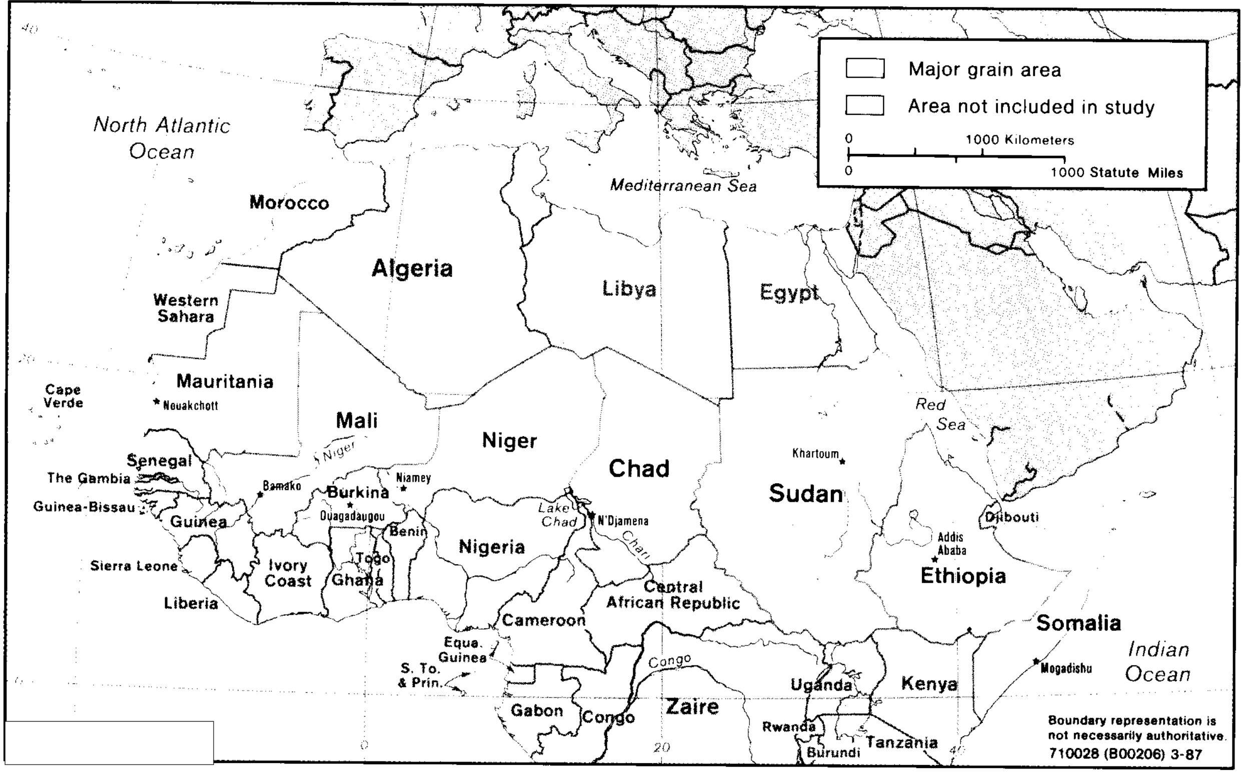

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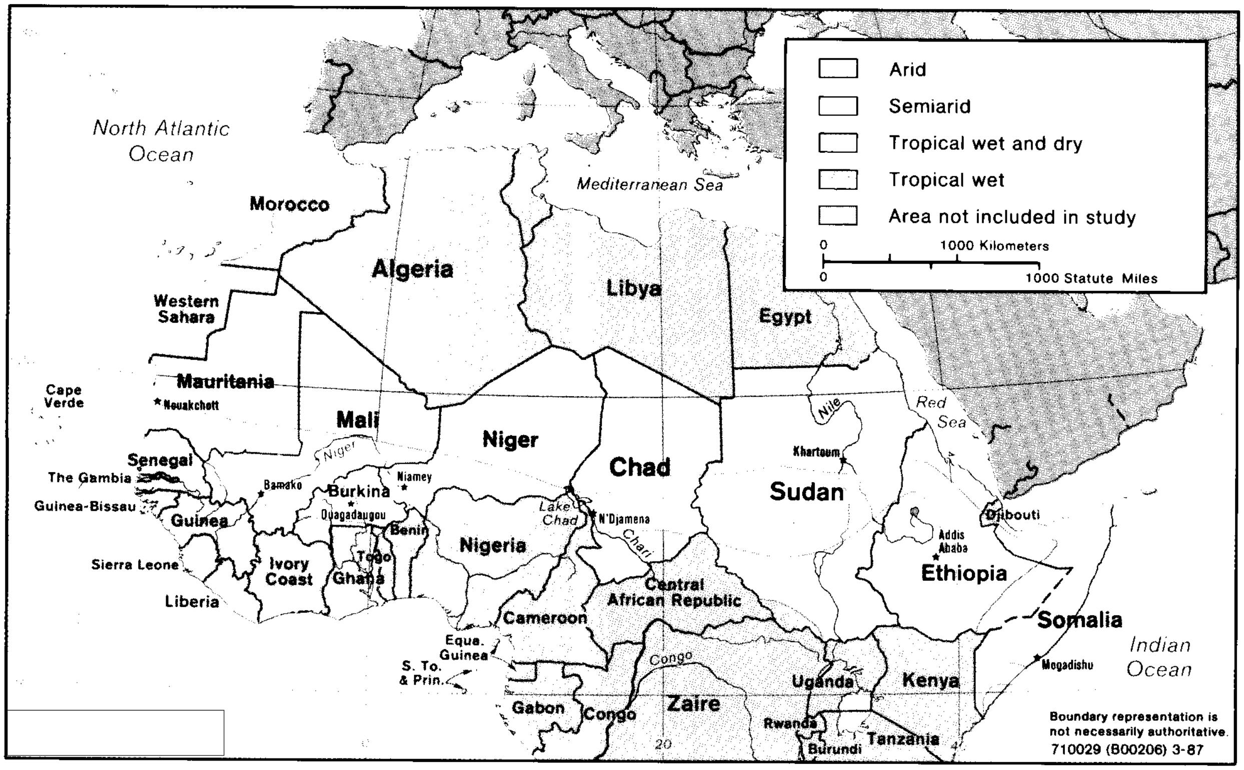
Figure 2. Climate Patterns



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Food Production in the African Sahel: Short-Term Relief, Long-Term Problems

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Introduction

The countries of the African Sahel and the Horn of Africa are among the poorest in the world. The vast majority of their 100 million people are essentially subsistence farmers whose meager existence is annually subject to the vagaries of the weather. An extended drought that covered most of the first half of this decade decimated crops in large portions of the region, leading to large-scale famine, mass migrations across international borders, increased political instability, and the need for massive external food aid. Despite improvements triggered by greater rainfall since 1985, the longer term outlook for the region's food balance remains grim, and large quantities of food aid will continue to be needed to stave off episodes of mass starvation and political instability.

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Rainfall Barely Adequate for Agriculture

Given the low level of agrotechnology in the region, rainfall is the key weather factor that determines the level of agricultural output in the Sahel and the Horn (appendix A). The agricultural areas of the eight countries included in our study—Mauritania, Mali, Burkina, Niger, Chad, Sudan, Ethiopia, and Somalia—(figure 1) are situated in a narrow transitional climatic zone between the Sahara Desert on the north and tropical forest on the south (figure 2). Total annual precipitation varies widely from year to year, but, as a general rule, most of the land receives less rainfall than the 400 millimeters (mm) per year needed for nonirrigated agriculture to be successful (figure 3).

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The western and central portions of the Sahel are characterized by natural grassland, nomadic herding, and rain-fed agriculture, with most rainfall occurring from July to September. There is very little water storage in this part of Africa, and, when the rains fail, cattle either die in large numbers or are driven southward in search of better grazing land and water. In the latter case, their numbers—combined with indigenous herds—often exceed the carrying capacity of the land, causing great damage to ecosystems and jeopardizing future feed resources. Most crops are produced at the subsistence level, and farmers obtain very low yields even in good years. Often the farmers carry little or no surplus from year to year, and the lack of a well-developed infrastructure—roads, motorized vehicles, and communication facilities—limits the amount of food that can be moved from surplus to deficit areas. The danger of famine arises quickly when the rains fail, yet indications of an impending famine may go undetected by governments and relief agencies for some time.

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Farther east, in the Horn, rainfall occurs in two seasons in most of Ethiopia and in parts of Somalia. Small amounts of precipitation fall in the spring—triggered by wind circulation from the Indian Ocean—but the major rains occur in the summer months. Ethiopia's large population—about 44 million people—and primitive agricultural techniques offset much of the food production advantage this region has, and generally the food balance is as precarious here as in the western and central parts of the Sahel.

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The Recent Drought in Historical Perspective

The recent drought in the eight countries along the southern fringe of the Sahara Desert has been the worst in this century. The drought, which has plagued most of the region since the late 1960s, was particularly intense during the period 1980-84. In fact, the United Nations has designated these countries as having the most serious food problems in Africa. Although recent rains have brought some relief, precipitation levels continue to be well below the long-term average (figure 4) and barely above the 400-mm annual rainfall requirement of many nonirrigated

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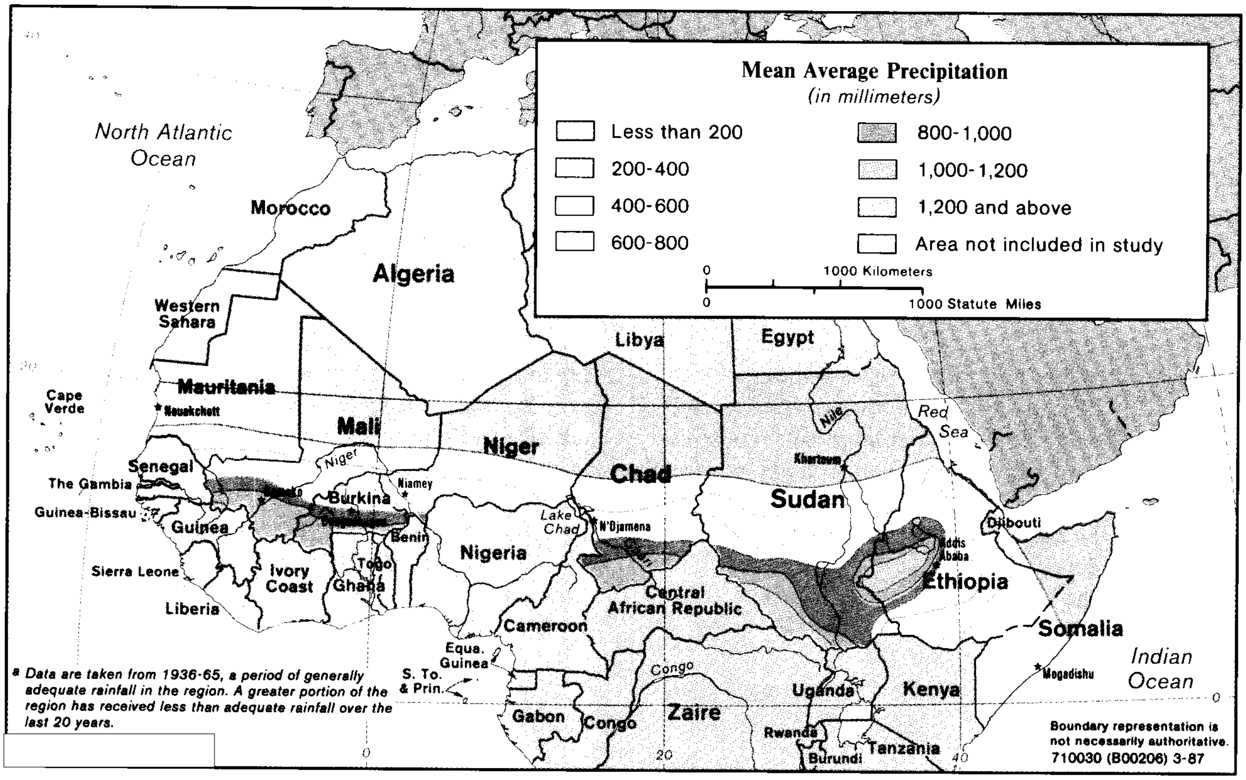
Figure 3. Precipitation During a Wetter Climatic Period[a]



[a] Data are taken from 1936-65, a period of generally adequate rainfall in the region. A greater portion of the region has received less than adequate rainfall over the last 20 years.

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Figure 4
The Sahel and the Horn: Average Annual Precipitation, 1921-85

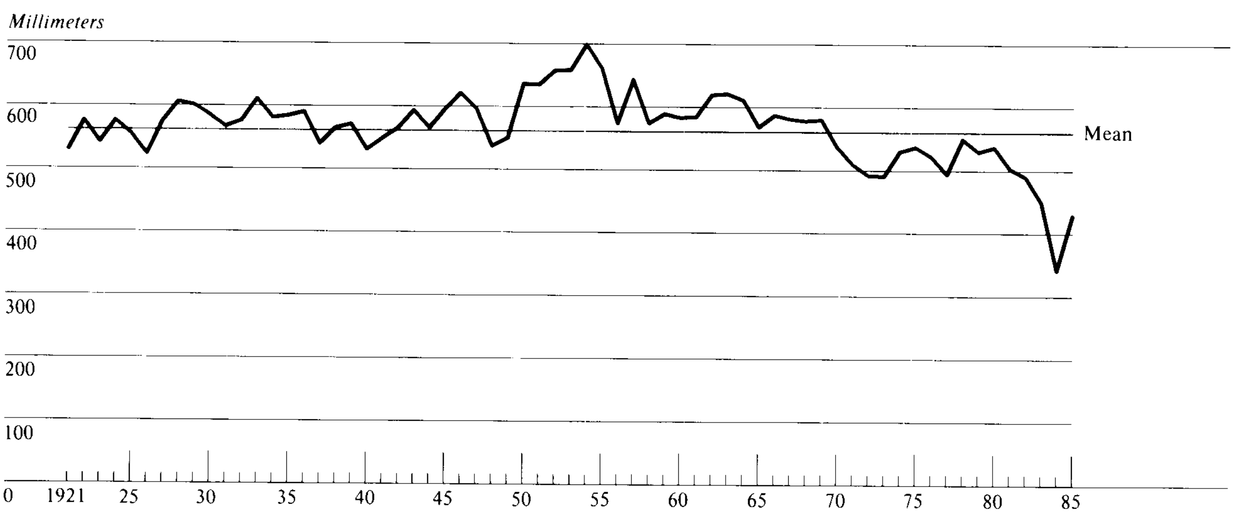

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Table 1
Occurrence of Droughts in the 1971-85 Period [a]

	Mauritania	Mali	Burkina	Niger	Chad	Sudan	Ethiopia	Somalia
1971	M			M	S			S
1972	S	M		S	S		M	
1973	S	M	M	S	M	M	M	M
1974								S
1975								
1976								S
1977	S	M	M					
1978								
1979								
1980	M	M	M					
1981		M	M	M			M	
1982	S	M	M	S	M	M		
1983	S	S	S	S	S	S		S
1984	S	S	S	S	S	S	S	S
1985					M			

[a] M — Mild drought (80 to 90 percent of normal precipitation).
S — Severe drought (less than 80 percent of normal precipitation).

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crops. Although this downward trend is unprecedented in duration and magnitude during this century, similar droughts have occurred periodically in this region since the early 1700s. The historical evidence indicates that similar episodes occurred in the 1740s and 1750s, 1820s and 1830s, and more recently in 1910-20.

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From a geographical perspective, drought in this region is not a localized phenomenon. Since the 1970s, its occurrence has been persistent and widespread across the eight countries included in this study (table 1). The line (isohyet) [1] representing the occurrence of 400 mm of precipitation moved southward an average of 85 kilometers (km) across the entire continent from 1966 to 1975, and 150 km in the period 1976-85 (figures 5a and 5b). The southward movement of the 400-mm isohyet essentially eliminated large agricultural areas from productive use. Also, there has been a marked decrease in annual precipitation in the agricultural areas nearer the southern fringes of the region where rainfall is generally more abundant. The agricultural areas of Mali, Niger, and Chad were especially hard hit in the 1966-75 period (figure 5a). Annual rainfall in these countries decreased 70 to 80 percent. The 1976-85 period saw a worsening and an expansion of the drought into Sudan, with more agricultural areas experiencing less than the minimum precipitation necessary to grow crops (figure 5b).

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Impact of Drought on Grain Production and Import Needs

The food balance in the region has clearly worsened since the mid-1960s. The decrease in precipitation since then has contributed to a general reduction of

[1] Precipitation is equal everywhere along an isohyet line.

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Figure 5a. Departure of 1966-75 Precipitation From 1936-65 Average

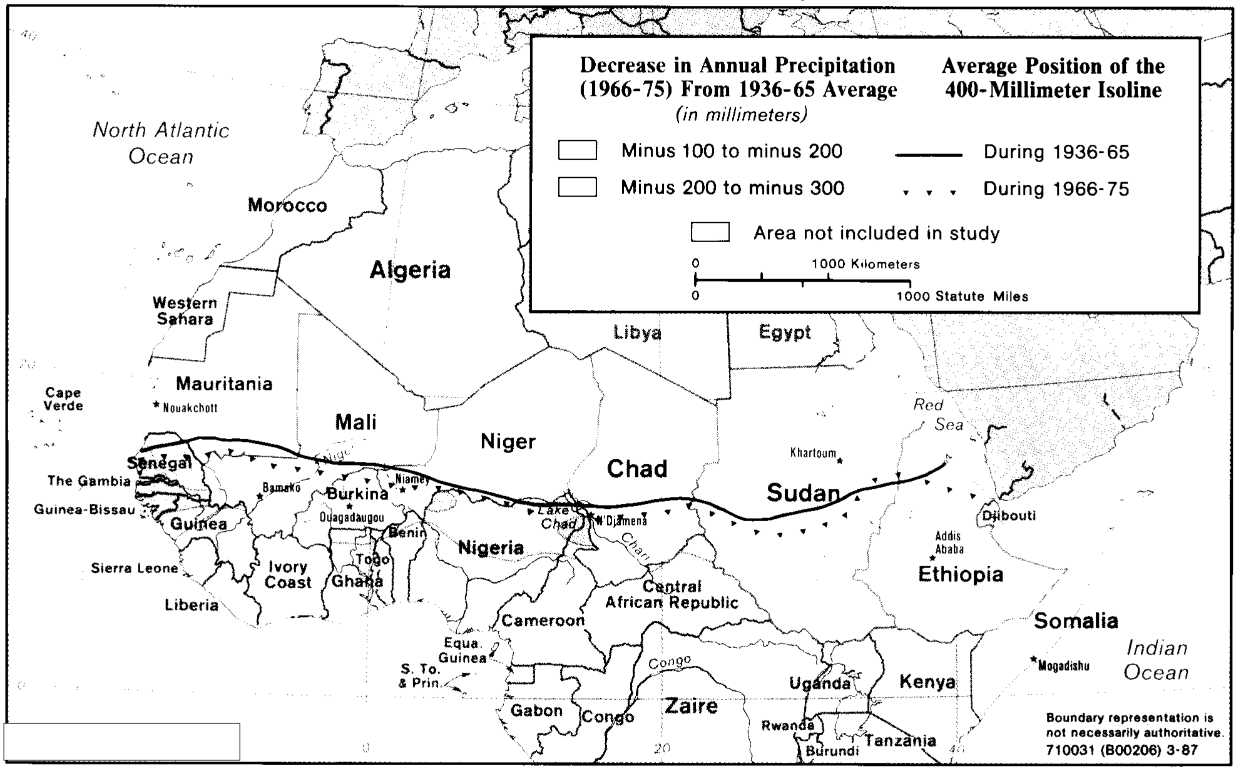

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Figure 5b. Departure of 1976-85 Precipitation From 1936-65 Average

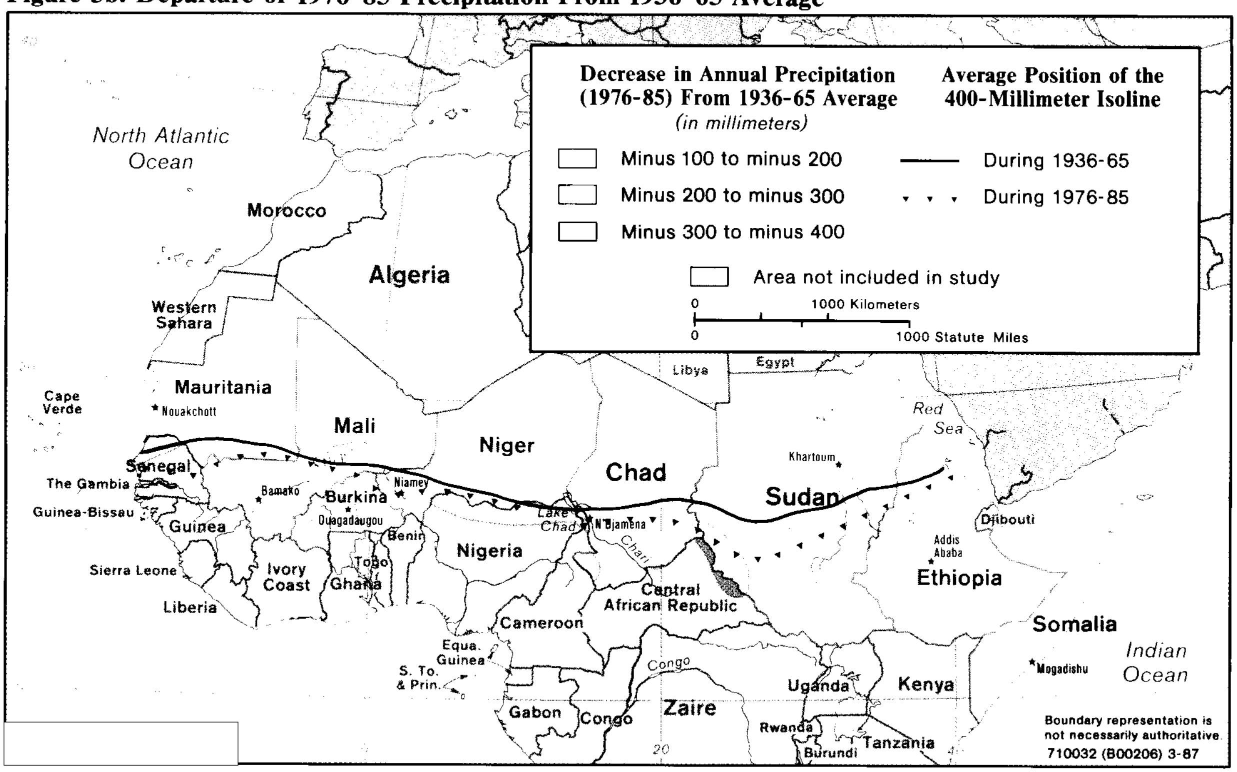

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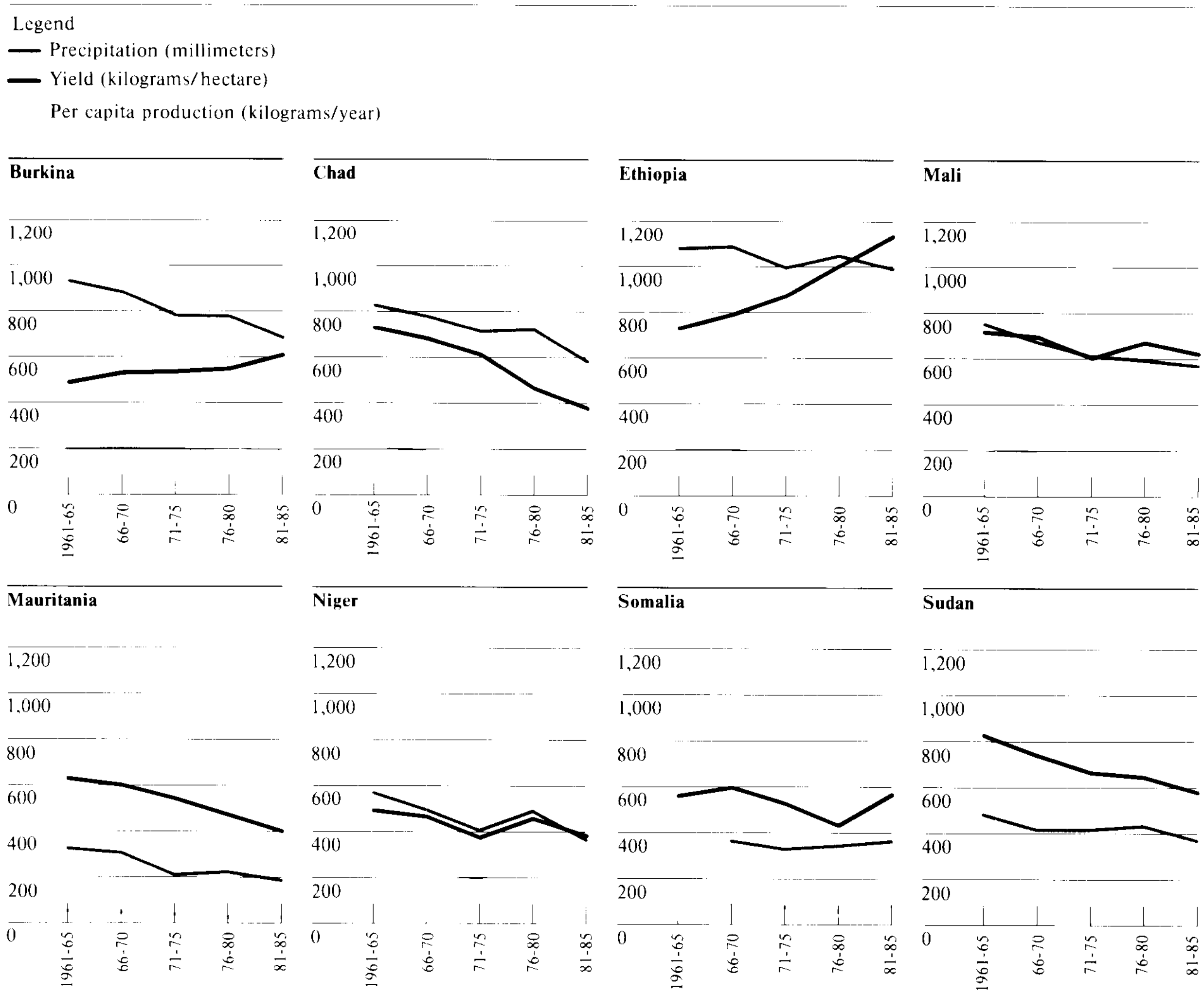
Figure 6
The Sahel and the Horn: Average Five-Year Precipitation, Grain Yields, and Per Capita Production, 1961-85



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grain yields in most of the eight countries (figure 6 and appendix B, tables B-1 and B-2). Generally, yield declines have matched precipitation shortfalls, except in Burkina and Ethiopia where yields have been increasing even with decreasing precipitation. In these two countries, other factors, such as increased use of fertilizers, have helped offset the effects of decreasing precipitation. Also, disease control measures in Burkina have allowed fertile river valley land to be brought into production. 25X1

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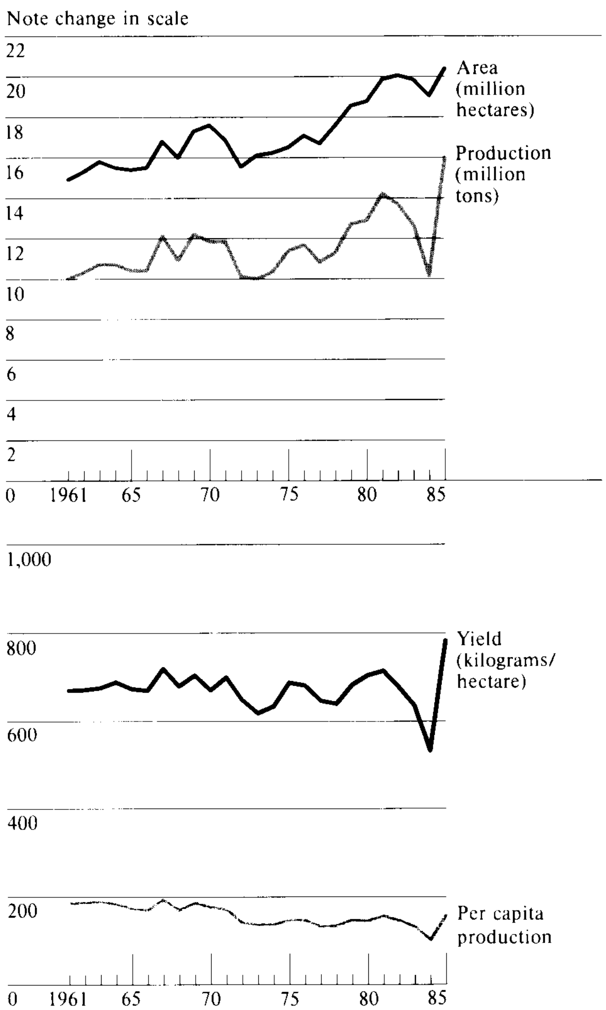
Figure 7
The Sahel and the Horn: Trends in Grain Production, 1961-85



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Reduction of grain area over the last 25 years in Ethiopia—as a result of the elimination of less productive land in favor of more intensive use of fertilizers on better land—has nevertheless kept production there from rising substantially. In most countries, yield reductions have been offset by steep increases in area planted to grain—despite the southward movement of the 400-mm precipitation isohyet—resulting in a net increase in the total amount of grain produced by the eight countries in the last 25 years (figure 7). However, much of the new area planted is of marginal quality. Moreover, per capita grain production, a good indicator of import and aid needs, has decreased steadily since the 1960s in many of the countries because of the high population growth rate—an average of 3 percent per year. 25X1

As a result of the intensified drought during the 1980-85 period, total grain imports—provided either commercially or as aid—for the eight countries tripled

The Population Problem

The population of the eight countries surveyed in this report is large and growing rapidly—particularly considering the paucity of arable land. According to the World Bank, total population in the region increased from about 51 million in 1960 to about 98 million in 1985—a near doubling in 25 years. Projected annual growth rates for the 1980-2000 period vary from 2.4 percent in Burkina and Somalia to 3.3 percent in Niger. Using the World Bank growth rates, we project that the total population of the region will reach 113 million by 1990. 25X1

The amount of arable land available to the growing population is comparatively limited. The total area of the region is slightly larger than that of the United States, including Alaska. In the United States about 20 percent of the land area is arable, but only about 4 percent of this part of Africa can be cultivated. This means that the region's average population density of about 2.5 persons per hectare of arable land is twice that of the United States. The population of the eight countries is widely but unevenly spread across the African continent, with Ethiopia and Sudan accounting for more than one-half of both the total population and arable land. 25X1

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Table 2
Grain Imports and Aid [a]

Thousand metric tons

	1981 [b]		1982		1983		1984		1985		Annual Average 1981/85	
	Imports	Aid	Imports	Aid	Imports	Aid	Imports	Aid	Imports	Aid	Imports	Aid
Total	**1,328**	**985**	**1,745**	**903**	**1,688**	**1,115**	**2,147**	**1,184**	**4,013**	**2,835**	**2,185**	**1,405**
Mauritania	160	106	219	86	236	71	273	129	278	135	233	105
Mali	99	50	157	66	155	88	291	111	345	266	209	116
Burkina	65	51	106	81	95	45	179	57	241	124	137	72
Niger	144	11	113	71	63	12	32	13	425	218	155	65
Chad	31	14	57	29	55	36	122	69	164	163	86	62
Sudan	266	195	366 [c]	194	445 [c]	330	491 [c]	450	1,200 [c]	812	554	396
Ethiopia	228	228	303	190	344	344	508	178	1,100	869	497	362
Somalia	335	330	424	186	295	189	252	177	260	248	313	226

[a] Aid is defined as grain donated to the countries.
[b] Unless specified to the contrary, all years are market years ending 30 June.
[c] Estimated from FAO trade yearbooks, which give import amount by calendar year.

Sources: *FAO Food Aid Bulletin No. 1*, January 1986; USDA/ERS, *World Food Aid Needs and Availabilities, July 1985.*

[redacted]

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from 1.3 million metric tons in 1980-81 to 4 million tons in 1984/85 (table 2). Over the 1980-85 period, food aid on average accounted for about two-thirds of total grain imported. In the 1984/85 market year (MY),[2] following the 1984 drought, about 70 percent of the total grain imported by the eight countries consisted of aid from donor countries. The high proportion of food aid in grain imports obviously reflects both the large need and the very limited ability of these countries to pay full commercial prices for food imports. [redacted]

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An improvement in the 1985 rainy season considerably diminished import and aid needs for the 1985/86 MY. Following good grain harvests in 1985, Burkina, Chad, Mali, Niger, and Sudan had local surpluses of grain. Estimates of the 1986 grain crops are generally excellent, although a locust and grasshopper infestation threatened to reduce somewhat the 1986 grain crop across the African continent. Preliminary estimates by the United States Department of Agriculture (USDA) and FAO indicate a grain crop approaching 17 million tons—the best harvest to date for the eight countries, and nearly 1 million tons higher than 1985. Nevertheless, according to FAO, many of the countries still need external assistance to support the procurement, storage, and internal distribution to deficit areas. [redacted] 25X1

Improving the Food Balance: A Long-Term Process

Despite improvement in agricultural production in 1985 and 1986 as a result of more abundant rainfall—although well below the long-term norms—we

[2] 1 July–30 June. [redacted]

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The Level of Agrotechnology

Land tilling tools on sale at the Bayelara Market east of Niamey (Niger). These tools typify the level of agricultural technology common across the Sahel region, where most farmland is still tilled by hand.

A team of oxen preparing the land for spring barley planting near Addis Ababa (Ethiopia). In contrast with the Sahelian countries, the use of animal traction is widespread in Ethiopia. Here, a combination of more favorable climate and soils and greater use of fertilizers helps raise the grain yields to levels two to three times those of the Sahelian countries. 25X1

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Agriculture in the Sahel and the Horn is generally at the subsistence level, with cultivation done mostly with hand tools and with a minimum of inputs. The use of mechanical traction—practically nonexistent for production of staple crops—suffers from a lack of capital investment, high fuel costs, and untrained manpower. Animal power is utilized extensively only in Ethiopia and is just beginning to be exploited in the other countries.

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Grain yields in the belt of countries stretching from Mauritania to Somalia are among the lowest in the world. In the eight countries surveyed, grain yields for 1981-85 ranged from less than 400 kg/ha in Chad and Niger to approximately 1,100 kg/ha in Ethiopia. These yields are one-sixth to one-half the world's average grain yields. The low productivity cannot be entirely explained by the harsh climate. The low level of agricultural development in the Sahel and the Horn—typified by the lack of fertilizers, mechanization, and technical know-how at the peasant farm level—also plays a major role.

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Development of higher yielding varieties of cereal crops that can thrive in the harsh environment lags far behind plant breeding work in other developing regions of the world. Consequently, crop breeders at the International Crop Research Institute in Mali estimate it may be at least 10 years before improved varieties of millet and sorghum could be made available to Sahelian farmers on a large scale. 25X1

Fertilizer is used mostly for cash crops in the eight countries, and application rates—averaging less than 1.0 kg/ha per year—are among the lowest in the world. In comparison, the world average is about 30 kg/ha and the US average is about 100 kg/ha. Staple cereals, such as millet and sorghum, are grown with little fertilizer, because of its high cost. 25X1

Only a very small percentage of crop land in these countries is irrigated. As in the use of fertilizer, irrigation resources are devoted mostly to cash crops. The World Bank estimates that Africa has less than one-twentieth the irrigated land of Asia. Nevertheless, cultivating land along river valleys in the region—for example, the Niger, Chari, and Nile Rivers—could provide an additional 2 million ha of agricultural land. However, infestations of tsetse fly, the carrier of sleeping sickness that affects both humans and cattle, presently discourage cultivation of large tracts of fertile land along the rivers. 25X1

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believe that the countries in the Sahel and the Horn will remain well short of food self-sufficiency. It is our view that even sustainable improvements in the food balance will be difficult to achieve. The drought of the 1970s and 1980s is but one of the factors that have contributed to the deterioration of the region's ability to feed itself. Two other major factors, largely resulting from failed government policies, are:

- The rapidly expanding populations. As highlighted earlier, population growth rates in the eight countries—3 percent on the average—are among the highest in the world. Moreover, with a population disproportionately made up of children who will be in their reproductive prime in the next five to 10 years, the growth rates will remain high unless effective birth control policies are instituted.

- The slow rate of improvement in applied agrotechnology. Increases in agricultural productivity in the region as a result of the introduction of new technology have generally lagged behind those in the rest of the world; the growth rate in agricultural output in the region has actually declined over the last 20 years.

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The green revolution that dramatically increased agricultural production and brought food self-sufficiency to countries like India and China—whose food balances were very precarious 20 to 30 years ago—has had little impact on the LDCs of Africa. The essential conditions that brought about the green revolution in Asia—availability of irrigated lands, major improvements in high-yield crop varieties, market accessibility through good transportation networks, and presence of a social infrastructure and educational systems favorable for the development and dissemination of technology—remain distant goals for the eight countries. Agricultural improvements in the region are made even more difficult by turbulent internal political situations and pursuit of short-term goals that have favored industrialization—limited as it is—at the expense of agricultural development, city dwellers at the expense of farmers, and sectarian gains at the expense of national unity.

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The Climate Outlook to 1990

There is some disagreement among climatologists on the trend in Africa's climate. The decrease in precipitation over the last 25 years is seen by some climatologists as heralding a climate change, characterized by a lower precipitation regime than that experienced over the last 50 or so years. We believe—like the majority of climatologists—that the present situation is still within the realm of the climate that Africa has been experiencing for at least the last 250 years; at a minimum, two other similar drought episodes have been experienced over this time period. During the next 10 to 20 years, a climate prediction consistent with this latter view could see a return to a higher precipitation regime as the most likely turn of events. Indeed, some climatologists who favor this view believe that the increased rains of 1985 were the beginning of such an upturn. 25X1

Because of these uncertainties, we developed three weather scenarios for the 1986-90 period that, in our judgment, are reasonable descriptions of the range of possible weather patterns and their likelihoods. These scenarios allow us to assess the likely range of grain production and imports—including aid—that will be needed during the period if nothing else changes:

- Our ***most likely rainfall scenario*** is an extrapolation into the future that gives greater weight to the most recent trend in rainfall.[3]
- Our ***worst case scenario*** is a continuation of the downward trend in precipitation experienced during the last 25 years in the region.
- Our ***best case scenario*** is a return to the weather of 1961-65, the wettest of the last 25 years. 25X1

[3] The rainfall predictions were performed using the ARIMA time series analysis procedure of the Statistical Analysis System (SAS) computer software package (appendix D). The ARIMA procedure analyzes and forecasts time series using an autoregressive integrated moving average model. The historical data bases are described in appendix B.

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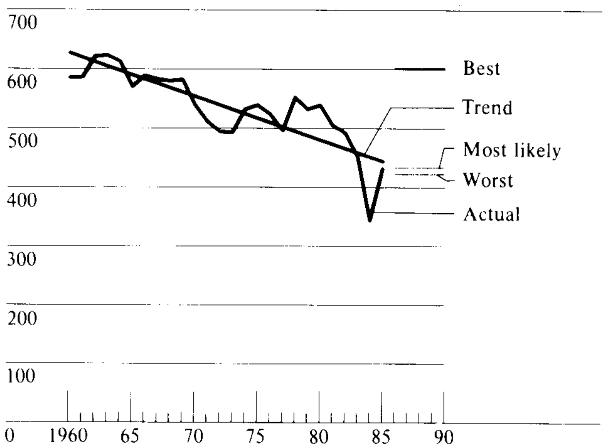
Figure 8
The Sahel and the Horn: Comparison of Precipitation for 1960-85 With Scenarios of Precipitation, 1986-90



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We have used historical data to compute annual average precipitation levels (figure 8) for 1986-90 consistent with each scenario. Under the ***most likely scenario***, we estimate that precipitation will average 432 mm annually over the region for the next five years, a slight decrease from the 444-mm yearly average experienced during 1981-85 and well below the long-term (1921-85) average of 561 mm (figure 4). This projection of a slightly drier climate on average during the rest of the decade than during 1981-85 is based on the influence of the dramatic drop in rainfall especially during the last 10 to 15 years. Moreover, studies show that rainfall patterns tend to closely follow trends of the immediate past.

25X1

Under the ***worst case scenario***—a continuation of the downward trend of precipitation of the last 25 years—we calculate an average regional precipitation decrease of about 23 mm, or 421 mm for the 1986-90 period. Calculations for the ***best case scenario*** show an annual regional precipitation average of 601 mm, a dramatic increase from the 1981-85 average of 444 mm.

25X1

We have also used the historical record to estimate rough probabilities of occurrence for each of the weather patterns we examined. Assuming no climate change, a precipitation regime at or better than the most likely scenario has a 50-percent probability of occurrence. We estimate that a rainfall regime like the worst case scenario—or lower—has about a 40-percent chance of happening and a regime approaching the best case scenario—or better—has less than a 1-percent chance of occurring. Annual precipitation for individual countries was estimated by regression from the regional precipitation estimates (appendix D).[4]

25X1

Grain Production Possibilities

Using rainfall assumptions, yield equations, and projections of area planted, we were able to estimate future grain production in each country in the region for the remainder of the decade (appendix C). Per capita grain production was then estimated using population projections. In general, our estimates indicate that prospects for improving the availability of food through domestic grain production are bleak. Unless weather conditions during 1986-90 come close to our best case scenario—a highly unlikely event, according to our calculations—per capita output of grain will most likely decline from the 1981-85 levels as a result of the region's rapidly growing population. Our estimates show this to be the case even though trend-line increases in land under cultivation show some increases in grain production overall.

25X1

[4] A correlation analysis shows that individual country precipitation is highly correlated with the regional precipitation, except for Somalia whose rainfall regime is mostly controlled by wind currents from the Indian Ocean.

25X1

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Table 3
Comparison of Historical and Estimated Annual Average Grain Production

	1981-85		Estimates, 1986-90 [a]					
	Production (*thousand tons*)	Per Capita (*kilograms*)	Best Weather Scenario		Worst Weather Scenario		Most Likely Weather Scenario	
			Production (*thousand tons*)	Per Capita (*kilograms*)	Production (*thousand tons*)	Per Capita (*kilograms*)	Production (*thousand tons*)	Per Capita (*kilograms*)
Total	**13,327**	**143**	**17,910**	**167**	**14,190**	**132**	**14,560**	**136**
Mauritania	51	29	90	45	40	20	50	25
Mali	1,032	135	1,290	147	970	110	1,000	114
Burkina	1,272	193	1,660	221	1,350	180	1,380	184
Niger	1,601	277	2,520	372	1,820	268	1,860	274
Chad	447	93	835	155	450	83	480	89
Sudan	2,940	145	4,400	187	3,030	129	3,090	131
Ethiopia	5,534	135	6,560	139	6,110	129	6,210	132
Somalia	450	86	555	93	420	70	490	82

[a] As a result of the interannual variability of weather, the range of grain production for individual years can vary by as much as ±20 percent from the given eight-country average, and even more for individual countries. Thus, we can expect total annual grain production to vary from about 11.6 to 17.5 million tons for the most likely weather scenario, 11.3 to 17 million tons for the worst case scenario, and 14.3 to 21.5 million tons for the best case scenario.

25X1

Compared with the annual average of 13.3 million tons for 1981-85, we estimate that average annual grain production for the region in 1986-90 will be (table 3):

- About 14.2 million tons in the ***worst case weather scenario***—about 1 million tons above the 1981-85 production average.
- About 14.6 million tons, or roughly a 10-percent increase over the 1981-85 average, if our ***most likely case scenario*** prevails.
- Approximately 17.9 million tons yearly production—or about a 35-percent increase over the 1981-85 level—under the ***best case scenario***.

Even in the very unlikely best case, average per capita grain production for the region would reach only about 167 kilograms (kg) /year—17 percent above the low 1981-85 average but still about 14 percent below the level needed to meet recommended FAO minimum nutritional standards (FAO MNS) (table 4).

25X1

Projected Grain Import Requirements

Because we estimate that per capita grain production will generally be insufficient to meet total food needs of the region for the remainder of the decade, we have

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Table 4
Estimates of Yearly Per Capita Grain Consumption, Compared With FAO MNS, 1981-85

	Consumption [a] (*kilograms*)	Requirement [b] (*kilograms*)	Consumption as a Percentage of Requirement
Mauritania	160	158	101
Mali	163	209	78
Burkina	213	211	101
Niger	303	315	96
Chad	111	167	66
Sudan	173	165	105
Ethiopia	147	198	74
Somalia	147	142	104
Average	167	194	86

[a] Per capita grain consumption, C, is estimated by the following formula:

$$C = (I + A + PROD)/P$$

where
I is average yearly grain imports excluding aid for 1981-85
A is average yearly aid from grain donations for 1981-85
PROD is average yearly grain production for 1981-85
P is average country population for 1981-85

[b] Amount of grain required to meet FAO MNS is based on data taken from USDA/ERS, *World Food Aid Needs and Availabilities, 1985.*

[redacted]

25X1

attempted to estimate the requirement for food imports and aid for each of the countries for the period. Recognizing that no single designator was available to measure grain needs, we projected grain import/aid requirements on the basis of two different grain need concepts:

- ***Status quo nutritional level.*** This gives grain supplies required to maintain per capita grain consumption at the average 1981-85 levels.
- ***Minimum nutritional standard.*** This gives grain supplies required to meet the FAO MNS.

These need standards allowed us to calculate a range of import requirements for each country during 1986-90 (table 5). [redacted]

25X1

Self-Sufficiency Not in the Cards

Even if the Sahel and the Horn experience the best weather we think is realistic to expect—our very unlikely best case scenario—we estimate that the region would still require an average of about 1.1 million tons per year in imports to maintain food supplies at recent levels of per capita consumption, and about 3.9 million tons of grain to meet the FAO MNS. Niger, Chad, Burkina, and Sudan would produce—on the average—sufficient grain to maintain recent nutritional levels and, except for Chad, would also meet the FAO minimum. Ethiopia, Somolia, Mauritania, and Mali, on the average, would all experience production shortfalls and require imports to maintain consumption at the 1981-85 average level. On the basis of recent economic trends, we estimate that 50 to 75 percent of the required grain—0.5-0.8 million tons of the required 1.1 million tons of grain per year—would have to be provided as aid, compared with 1.4 million tons supplied by donors on average during 1981-85. [redacted] 25X1

Import Needs Likely To Increase Substantially

It is more likely that weather conditions during the rest of this decade will be slightly drier than the 1981-85 average—our most likely scenario. In this case, we estimate that all eight countries will require yearly grain imports totaling about 3.3 million tons, or 50 percent more than the 1981-85 average, to maintain the status quo per capita consumption. Assuming no improvements in the countries' ability to buy grain on the open market, we estimate that approximately 1.7-2.5 million tons of the 3.3 million tons required would have to be provided by donor countries. According to our estimates, the hardest hit would be Sudan, with an import need of almost 1 million tons yearly—400,000 tons above the 1981-85 average. Others with large import needs under this scenario include Ethiopia, Somalia, and Mali. For the group to meet the FAO MNS under this scenario, imports of about 6.3 million tons per year would be needed—triple the average imports during the 1981-85 period [redacted] 25X1

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Table 5
Estimates of Average Annual Grain Import Requirements, 1986-90 [a]

Thousand tons

	Weather Scenarios						1981-85 Average Imports
	Best		Worst		Most Likely		
	SQ [b]	MNS [c]	SQ [b]	MNS [c]	SQ [b]	MNS [c]	
Total	**1,080**	**3,940**	**3,710**	**6,670**	**3,340**	**6,310**	**2,185**
Mauritania	230	230	280	280	270	270	233
Mali	140	560	460	880	430	850	209
Burkina	0	0	250	230	220	200	137
Niger	0	0	240	320	200	280	155
Chad	0	60	150	450	120	420	86
Sudan	0	0	1,040	850	980	790	554
Ethiopia	380	2,790	830	3,230	730	3,140	497
Somalia	330	300	460	430	390	360	313

[a] Because of interannual weather variability and resultant variability in annual production (as much as ±20 percent from the five-year average for the total eight-country production), the individual year's import/aid requirements can vary substantially from the above averages. Includes grain both imported commercially and obtained through aid.
[b] SQ = Status quo nutritional level equated to per capita grain consumption during 1981-85 (table 4).
[c] MNS = FAO minimum nutritional standard.

25X1

Risk of Famine Clear

If the weather follows the trend of the last 25 years—our worst case scenario—we estimate that about 3.7 million tons of grain imports will be required yearly to maintain per capita consumption at the average level of the 1981-85 period. Approximately 2.5-3 million tons of the required 3.7 million tons would have to be supplied as aid. The major importers would be Sudan and Ethiopia, according to our estimates. To meet the FAO MNS standards, the eight countries would require a total of 6.7 million tons of grain imports per year, with Ethiopia's bulging population needing almost half this amount. Not only are these import volumes well beyond affordable levels, they also are substantially greater than any import levels reached to date. Moreover, these volumes would exceed the capacity of the region's very limited transportation system to move grain to areas of need. Consequently, there would be a real risk of a return to famine conditions in a number of countries.

25X1

Risks for the Region

Economic Outlook Grim

The countries of the Sahel and the Horn are clearly among the poorest in the world. Under the best of conditions, their economies are barely able to meet essential domestic needs and pay foreign obligations. Despite massive injections of international food aid, the cost of importing food has seriously increased the burden on the balance of payments of the countries and threatens their financial viability. The annual cost of grain imports rose on average from $90 million in 1971-75 to $475 million in 1981-85, absorbing almost half of the region's increase in export earnings. Consequently, the small but hard-won gains in foreign

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Table 6
Estimates of Annual Average Grain Import Costs, 1986-90 [a]

Million US $

	Weather Scenarios						1981-85 Average
	Best		Worst		Most Likely		
	SQ [b]	MNS [c]	SQ [b]	MNS [c]	SQ [b]	MNS [c]	
Total	**215**	**725**	**750**	**1,250**	**675**	**1,180**	**475**
Mauritania	60	60	70	70	70	70	46
Mali	35	140	115	215	105	210	63
Burkina	0	0	60	55	50	45	26
Niger	0	0	45	55	35	50	32
Chad	0	10	20	60	15	55	17
Sudan	0	0	220	180	205	165	113
Ethiopia	65	465	140	535	120	520	93
Somalia	60	55	85	80	75	65	85

[a] On the basis of average grain price per ton for each country, calculations are made using World Bank grain price forecasts for 1986-90 and estimates of average grain import needs (table 5). Estimates are rounded to nearest US $5 million.
[b] SQ = Status quo nutritional level.
[c] MNS = FAO minimum nutritional standard.

25X1

trade will do little to spur economic development in the region as long as 25 percent of earnings are devoted to grain imports.

25X1

Without additional international aid, the annual average cost of grain imports will approach $700 million to hold nutritional levels stable under the most likely weather scenario (table 6). Countries faced with the highest costs would be Sudan, with more than $200 million annually, and Ethiopia and Mali, with more than $100 million each. If, however, the eight countries were to try to achieve the minimum FAO MNS, the average yearly cost of grain imports would be about $1.2 billion—clearly well beyond what the region's economies can afford.

25X1

Political and Social Problems Likely To Increase

Our estimates suggest that, on average, the food balance in the Sahel and the Horn is likely to worsen over the rest of the decade. We believe that food shortages over the next five years will have the potential to further aggravate political and social problems for most of the eight countries:

- The Governments of Mauritania, Chad, Mali, Sudan, and Niger could face greater risk of military coups. Indeed, drought and food shortages were among the root causes of coups in Mauritania and Niger in the recent past.

- The Governments of Ethiopia, Somalia, and Burkina may not fall, but refugees fleeing famine in these countries could create political and economic problems and hardship for neighboring countries. Such migrations during famines are common in the region.

- The opportunities for external subversion can be increased. In particular, the Libyans, who are already using humanitarian aid as a means to penetrate the western provinces of Sudan, can be expected to exploit the need for food to advance their

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penetration of Niger, Chad, and Mauritania, if the opportunity arises. Mauritania is likely to be the target of Moroccan, Algerian, and Soviet subversion as well.

- More farmers are likely to be driven from their land, thus hastening the rural-to-urban migration, which is occurring in all of the countries. Such migrations place additional financial and managerial burdens on the political and economic institutions needed to manage agricultural problems, thus reducing chances for future agricultural improvement. Most governments in the region are still struggling to manage enlarged urban populations resulting from the current drought. Expanded urban populations fed by displaced subsistence farmers can become a breeding ground for political instability.

25X1

Implications for the United States

On the basis of our analysis, we believe that the United States and other Western countries will be asked to provide substantial food aid to the Sahel and the Horn for the remainder of the decade, and probably much longer. The chance of a dramatic increase in annual average rainfall during the next five years that could change this outlook is 1 in 100. Over the longer term, if the current population growth rate remains unchecked and the drier weather trend continues, import requirements could overload the region's primitive transport infrastructure, possibly resulting in widespread famine. 25X1

In our judgment, much could be gained from Western agrotechnical assistance and encouragement of policies that favor increased domestic output. For example, US seed companies are particularly well qualified to assist in the development of drought-resistant grain varieties. Agrotechnology is clearly an area where the West, and the United States in particular, have a decided advantage over the Soviet Union. Emphasis on agrotechnical assistance from the West would contrast sharply with Moscow's general unwillingness and inability to provide agrotechnology to Third World countries. To make a program of technical assistance viable, the governments of the region would also need to provide low-cost credit to farmers for purchase of additional agricultural inputs. Past programs to introduce new agrotechnology into the region, however, have been largely ineffective because the governments have failed to provide such support to the farmers. 25X1

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Appendix A

Country Perspectives on the Drought

Mauritania

This sparsely populated country of only 1.9 million people until recently had a pastoral economy based on nomadic herding. Annual average grain production for 1981-85 amounted to only 50,000 tons, less than 1 percent of the total grain production of the eight countries. The prolonged drought conditions of the last 25 years desiccated the rangelands, causing a massive influx of nomads into urban centers and a gradual shift from a diet based on animal products to one based mainly on cereals. Declining rainfall levels in the agricultural and range areas of the south culminated in the worst drought of the century in 1984, when only 21,000 tons of grain were produced. The severe food shortage in 1984/85 was alleviated mostly by food aid—grain—that totaled 135,000 tons. The situation improved dramatically in 1985, when for the first time in 10 years rainfall approached normal levels in all regions of the country, resulting in a record grain production of 86,000 tons. Preliminary United States Agency for International Development (USAID) estimates of the 1986 grain crop indicate an excellent harvest approaching 100,000 tons, even after accounting for a 10-percent loss as a result of the grasshopper infestation. Nevertheless, the FAO estimates that Mauritania would have to import more than 180,000 tons of grain to meet its requirements in the MY 1986/87, half of which would have to be aid.

25X1

Mali

Mali annually produces 1 million tons of grain—mainly millet and rice—almost 8 percent of the grain output in the eight-country region. Although yields have not declined as dramatically as in some of the other countries, a rapid increase in population—from 4 million to 8 million in the last 25 years—has caused per capita grain production to decrease sharply from an average of 224 kg in 1961-65 to 135 kg in the 1981-85 period. Over the 1981-85 period, the decrease in per capita production necessitated average annual grain purchases of 209,000 tons and additional average yearly food aid of 116,000 tons. 25X1

Although above-normal rains and a near-record area planted to grain contributed to a record 1.4-million-ton grain crop in 1985, the FAO estimates that Mali needs to import 275,000 tons of grain in MY 1987 to compensate for local food shortages in the north. According to FAO, about 105,000 tons of the total will have to be furnished as aid. Preliminary reports indicate that, overall, Mali has obtained a record grain crop of 1.8 million tons in 1986, following good rains and preventive measures against grasshopper infestation. Nevertheless, the north is still plagued by grain shortages caused by localized drought. 25X1

Burkina

Although precipitation has been decreasing overall in the last 25 years, grain yields in Burkina have been steadily increasing at a rate of about 11 kg/hectare (ha) per year. The improvement results from the use of better farming methods and irrigation countrywide. It also reflects increased output from the fertile, less-drought-prone southwest part of the country where major progress has been made in the eradication of rinderpest and tsetse fly. Nevertheless, the country suffers from localized droughts, especially in the northern and eastern regions, and from inadequate distribution networks that prevent surplus cereal production from reaching drought-stricken areas. For example, the food shortfalls in the drought-stricken northern and eastern regions in 1983 and 1984 could have been alleviated because overall grain production was probably adequate, but the surpluses elsewhere could not be moved to the deficit regions. 25X1

Grain production in the 1960s and 1970s was sufficient to absorb the impact of the population growth on food requirements. The situation worsened, however,

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in the first half of this decade. Despite increasing yields, grain imports had to be increased nearly fourfold—from 65,000 tons in MY 1980/81 to 241,000 tons in MY 1984/85—to cover the domestic grain shortfall. Increased rainfall in 1985 gave temporary relief, and a record 1.6-million-ton crop greatly improved the food situation by yearend. Prospects for the 1986 grain crop were generally very favorable; only some areas in the north faced a poor harvest because of dry conditions and the grasshopper infestation. FAO estimates that Burkina will need about 70,000 tons of additional imports and/or aid in MY 1987 to meet its requirements. [redacted]

25X1

Niger

Using grain production as a measure, Niger has been another better-than-average agricultural performer over the long term, notwithstanding the decreasing precipitation levels since the 1960s. The area planted to grain has doubled over the last 25 years and output has increased by 80 percent, according to FAO reporting. Sharply decreasing precipitation levels in the 1980s, however, reversed an improvement in yields that had taken place in the 1970s and that had brought Niger close to grain self-sufficiency. The 1984 drought was especially severe, causing the lowest grain yields in nine years and the need to import record levels of grain in MY 1984/85. The return of the rains in the summer of 1985 resulted in overall good grain production, although several northern regions continued to suffer the effects of long-term drought. Although Niger's per capita grain production of 277 kg during the 1981-85 period was the highest of the eight countries surveyed, it was not sufficient to meet food requirements. Grain imports, including purchases and aid, averaged 155,000 tons annually during the period. Prospects were for an above-average grain crop in 1986, with only slight losses expected because of localized grasshopper infestations. The FAO estimates that Niger needs to import only about 18,000 tons of grain to meet its requirements in MY 1987, half of which to be provided as aid. [redacted]

25X1

Chad

The precipitation decrease during the last 25 years caused a decline of almost 40 percent in Chadian grain production from the early 1960s to the mid-1980s. The production shortfall coupled with a steep increase in population—from 3 million in 1960 to 5 million in 1985—reduced per capita grain production from 222 kg/year in 1961-65 to 93 kg/year in the 1981-85 period. The severity of the recent drought has caused the level of Lake Chad to drop perilously low, threatening fisheries and agricultural projects. Indeed, the 1984 drought was so severe that grain production was reduced to 260,000 tons, little more than half of average production. The prolonged drought also decimated livestock herds, causing many nomads to shift to a dietary mainstay of cereals, further increasing grain consumption requirements. [redacted]

25X1

Increased precipitation during the 1985 rainy season resulted in a 690,000-ton harvest—the best in 20 years—and brought considerable relief to the famine-stricken country. Even with a substantial 1985 harvest and 163,000 tons of grain aid received in 1985, Chad still needs to receive 19,000 tons of grain aid in MY 1987, according to FAO reports. FAO and USDA reports indicate that the 1986 grain crop was above average, although up to 300,000 ha of cropland were threatened by grasshoppers and locusts, which may have considerably reduced the harvest if controls were not effective. The war with Libya is also significantly disrupting agricultural activities and the transportation of surplus grain to deficit areas. [redacted] 25X1

Sudan

Despite decreasing precipitation and grain yields over the last 25 years, Sudan's grain production has increased from an average 1.6 million tons in 1961-65 to 2.9 million tons in 1981-85, according to FAO reports. The Sudanese were able to increase output by nearly tripling the area planted to grain during the

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period. Between the early 1960s and 1980 annual per capita grain production increased from 125 kg to 147 kg, a noteworthy achievement considering that the population increased almost 60 percent during the same period—from about 11.8 million to 18.7 million. However, a drastic decrease in precipitation in the 1980s and correspondingly low grain yields reversed the trend toward food self-sufficiency. Indeed, the 1984 drought, which cut normal grain production more than one-third, caused Sudan to import a record 1.2 million tons of grain in 1985, more than two times the 1984 level. In 1985 good rains and a record area planted to grain reversed the trend and resulted in a record 4.6-million-ton grain crop. The 1986 harvest apparently was good, mostly because of sufficient rains in the major millet and sorghum regions in the east. The insurgency in the southern areas of the country, however, is hampering grain distribution and causing local shortages. The FAO estimates that Sudan needs to import about 400,000 tons of grain, 75 percent through aid, to meet its requirements in MY 1987. [redacted]

25X1

Ethiopia

Ethiopia's grain yields have been rising at an annual trend rate of almost 24 kg/ha over the last 25 years, despite the fact that precipitation levels have been decreasing. Nevertheless, reduction of grain area and steep population growth over the last 25 years have greatly reduced the per capita grain production. As the population increased from 21 million in 1961 to 43 million in 1985, per capita grain production fell from about 214 kg/year in 1961-65 to 135 kg/year in 1981-85. Average yields have risen primarily because of greater use of fertilizers. The tenfold increase in use of fertilizers—from less than 1 kg/ha in the 1960s to more than 10 kg/ha in the 1979-83 period—makes Ethiopia the largest user of mineral fertilizers among the countries included in this study. Higher average yields may also reflect the abandonment of less productive land as a result of internal strife or erosion. [redacted]

25X1

Severe drought, aggravated by civil war, lowered grain production in 1984 by 650,000 tons, compared with the previous five-year average. As a result, record grain purchases and aid were required to sustain the famine-stricken population. Near-normal rainfall in 1985 improved the situation somewhat, although the estimated 5.2-million-ton grain harvest still was not sufficient to meet the grain needs of the population. USAID and FAO estimates of 1986 grain crops indicate an above-average grain production of more than 6 million tons, about 1 million tons short of Ethiopia's needs. Carryover stocks from aid received in 1985 and 1986, however, limit 1987 grain aid needs to less than 500,000 tons at worst. [redacted] 25X1

Somalia

Somalia is not a large grain producer, its agricultural sector is based mainly on livestock. Somalia's average grain production—450,000 tons for 1981-85—represents only 3 percent of the total grain production of the eight countries of the region. According to the FAO, grain production and yields have increased during the last 10 years. The increase resulted mainly from the expansion of agriculture into fertile river basins in the south and the increased planting of corn, which produces higher yields than other grains. [redacted] 25X1

Somalia has been heavily dependent on grain imports—most of it in the form of aid—to meet its grain requirements. In the period 1981-85 it imported more than 40 percent of its annual average grain consumption of 760,000 tons. Even with a record 1985 harvest of 619,000 tons and the good harvest expected in 1986, Somalia still will have to import about 175,000 tons—again mostly aid—to meet its grain needs in MY 1987, according to the FAO. [redacted] 25X1

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Appendix B

Data Bases Developed for the Study

Weather and Climate [5]

An extensive new precipitation data base of the entire African continent was required to undertake this study. We assembled a computerized data base for making climate estimates from weather records obtained from the National Center for Atmospheric Research (NCAR), the National Oceanographic and Atmospheric Administration (NOAA), the Agency for International Development, the Somali Meteorological Office, and the International Livestock Center for Africa (ILCA).

25X1 The climate data base includes monthly precipitation and temperature recordings from about 1,400 climatic stations over the African continent. Approximately 300 stations are located within latitudes 5°N and 25°N, the area covering the eight countries chosen for this study. Although some stations have records dating back to the late 1800s, the bulk of the stations did not start reporting until the 1920s. Sufficient data to permit reliable annual estimates of precipitation in the region first became available in the 1920s. Nonetheless, data series since then are plagued by recurring gaps.

25X1 Three procedures were used to estimate monthly precipitation data for stations that had some data missing during the 1921-85 period:

- In the simplest procedure, zero monthly precipitation values were substituted for missing data whenever the available data, covering 10 or more years, showed that similar months had experienced no precipitation; such dry spells are common in desert locations.

- In a second procedure, linear regression equations were developed between nearby stations and were used to estimate missing monthly values.

- In a third procedure, monthly precipitation values were estimated as functions of latitude and longitude, and these regression equations were used to fill in the missing data.

Statistical analysis of the augmented data bases confirmed the reasonableness of the gap-filling procedures and established an acceptable level of confidence in the data bases for projection purposes. The resultant annual rainfall data averaged over each country are given in table B-1. 25X1

Grain

Grain production, area, and yield data for the eight countries of our study were assembled from data obtained from USDA's Foreign Agricultural Service, UN/FAO publications, USAID reports, and various country agricultural handbooks. The data base covers the years 1961-85 and includes all of the major grains produced in the area (millet, sorghum, barley, wheat, corn, rice, and teff). Total grain production, area, and yields for the individual countries are shown in table B-2. 25X1

Population

Population data for the eight countries are presented in table B-3. The data were obtained from FAO yearbooks and a 1984 Ethiopian population census report. The population projections to 1990 were made using growth rates published by the World Bank (World Bank, *Toward Sustained Development in Sub-Saharan Africa*, 1984). 25X1

[5] Climate is weather over a longer period. For example, daily precipitation is used to describe weather, while mean precipitation for 30 years or longer is used to characterize climate. Both are averages and both change as time passes. 25X1

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Table B-1
Annual Average Precipitation Over Agricultural Areas

Millimeters

	Mauritania	Mali	Burkina	Niger	Chad	Sudan	Ethiopia	Somalia	All [a]
1961	329	695	829	587	872	495	1,133	NA	585
1962	286	765	1,007	595	888	482	976	NA	620
1963	305	743	967	460	830	474	1,107	NA	622
1964	364	776	995	682	883	527	1,167	NA	612
1965	357	793	868	537	665	450	1,017	NA	569
1966	309	707	873	506	818	417	1,060	290	588
1967	312	733	850	596	779	458	1,238	565	582
1968	229	596	957	451	772	413	1,083	440	579
1969	443	691	925	471	756	390	1,021	157	581
1970	256	648	819	472	781	421	1,038	381	538
1971	216	659	793	385	671	421	1,025	256	510
1972	118	545	793	363	700	396	957	556	493
1973	176	570	698	334	643	390	974	299	492
1974	256	634	851	483	757	447	1,022	200	531
1975	301	664	787	486	816	447	1,014	348	538
1976	248	649	836	485	718	439	1,111	258	523
1977	149	565	724	453	677	414	1,103	380	495
1978	275	617	834	598	781	462	1,005	400	551
1979	235	590	786	471	669	441	1,014	321	531
1980	218	559	720	461	773	430	1,019	373	538
1981	254	662	725	399	684	439	977	577	504
1982	185	575	715	338	650	353	1,081	394	491
1983	119	439	624	364	555	342	1,056	205	451
1984	147	453	549	285	436	236	833	254	343
1985	241	737	825	460	600	501	1,012	400	430

[a] Areas between 5°N and 25°N latitude.

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Table B-2
Grain Production, Area, and Yields

	Production, All Grains *(thousand metric tons)*								
	Mauritania	Mali	Burkina	Niger	Chad	Sudan	Ethiopia	Somalia	Total [a]
1961	60 [c]	1,000	716	785	700 [c]	1,669	4,830	250 [c]	10,000
1962	60 [c]	1,137	888	827	700 [c]	1,588	4,850	250 [c]	10,300
1963	60 [c]	946	882	859	902	1,761	4,980	250 [c]	10,700
1964	60 [c]	874	1,150	1,100	718	1,548	5,030	250 [c]	10,700
1965	60 [c]	917	992	890	619	1,456	5,220	250 [c]	10,400
1966	60 [c]	926	1,002	969	672	1,182	5,321	250 [c]	10,400
1967	60 [c]	1,037	1,023	1,128	684	2,436	5,487	250 [c]	12,100
1968	60 [c]	926	1,014	798	699	1,260	5,923	250 [c]	10,900
1969	60 [c]	1,118	1,041	1,011	696	1,954	6,053	250 [c]	12,200
1970	60 [c]	946	1,053	799	656	2,139	5,893	283	11,830
1971	60 [c]	867	1,087	851	690	2,192	5,851	230	11,830
1972	60 [c]	696	1,090	787	532	1,848	4,762	267	10,100
1973	60 [c]	696	845	761	460	2,132	4,814	231	10,000
1974	60 [c]	746	1,190	1,122	520	2,439	4,012	226	10,320
1975	51	911	1,226	911	666	2,698	4,668	243	11,374
1976	44	1,069	1,174	1,522	619	2,574	4,419	252	11,673
1977	29	937	1,058	1,118	565	2,858	3,997	263	10,825
1978	28	1,253	1,144	1,509	553	2,789	3,753	255	11,287
1979	46	1,124	1,160	1,608	462	3,002	5,036	258	12,696
1980	81	866	1,005	1,753	507	2,758	5,704	263	12,887
1981	82	1,112	1,291	1,681	403	3,923	5,334	378	14,204
1982	43	1,019	1,204	1,691	444	2,453	6,374	400	13,678
1983	23	875	1,148	1,730	443	2,315	5,750	358	12,642
1984	21	752	1,132	1,070	256	1,449	4,990	495	10,165
1985	86	1,402	1,586	1,834	690	4,562	5,220	619	15,999

	Area, All Grains *(thousand hectares)*								
	Mauritania	Mali	Burkina	Niger	Chad	Sudan	Ethiopia	Somalia	Total [b]
1961	100 [c]	1,495	1,697	1,712	1,000	1,813	6,690	440 [c]	14,900
1962	100 [c]	1,502	1,826	1,723	1,000	1,949	6,790	440 [c]	15,300
1963	100 [c]	1,600	1,884	1,894	1,000	1,994	6,850	430 [c]	15,800
1964	100 [c]	1,172	2,135	1,862	1,000	1,983	6,920	370 [c]	15,500
1965	100 [c]	1,135	1,919	1,874	1,000	2,011	6,980	430 [c]	15,400
1966	100 [c]	1,111	1,973	1,955	1,000	1,954	7,062	430 [c]	15,500
1967	100 [c]	1,226	2,168	1,992	1,000	2,674	7,177	430 [c]	16,800
1968	100 [c]	1,696	1,609	2,022	1,000	1,901	7,265	440 [c]	16,000
1969	100 [c]	1,731	2,121	2,061	1,000	2,533	7,354	430 [c]	17,300
1970	100 [c]	1,566	2,051	2,090	1,000	2,910	7,453	425	17,600
1971	100 [c]	1,482	1,902	1,987	1,020	2,983	7,009	384	16,870
1972	100 [c]	1,155	1,916	1,935	979	2,830	6,125	509	15,550
1973	100 [c]	1,125	1,916	2,463	887	3,478	5,700	451	16,120
1974	100 [c]	1,430	2,203	2,787	901	3,830	4,546	434	16,240
1975	167	1,331	2,237	2,819	900	3,957	4,584	511	16,506
1976	80	1,486	2,184	3,187	1,122	4,084	4,329	614	17,086
1977	70	1,380	2,029	2,713	1,150	4,297	4,440	617	16,696
1978	119	1,074	2,160	3,021	1,190	4,358	4,492	581	17,595
1979	121	1,650	1,959	3,619	1,190	4,480	4,935	617	18,571
1980	112	1,630	1,810	3,861	1,196	4,465	4,626	575	18,775
1981	153	1,682	2,260	4,041	1,196	5,269	4,553	723	19,877
1982	151	1,617	2,160	4,244	1,190	4,919	5,024	759	20,064
1983	111	1,670	2,030	4,274	1,183	4,941	4,855	780	19,844
1984	110	1,670	2,030	4,158	1,185	4,457	4,705	800	19,065
1985	110	1,700	2,025	4,200	1,175	5,300	5,005	897	20,412

	Yield, All Grains *(kilograms per hectare)*								
	Mauritania	Mali	Burkina	Niger	Chad	Sudan	Ethiopia	Somalia	Total
1961	600 [c]	669	422	458	700	920	720	510 [c]	671
1962	600 [c]	756	482	479	700	814	715	510 [c]	673
1963	740	591	468	453	902	883	725	510 [c]	677
1964	600 [c]	745	539	590	718	780	725	680 [c]	690
1965	600 [c]	807	517	474	619	724	750	580 [c]	675
1966	600 [c]	833	541	495	672	604	753	580 [c]	671
1967	600 [c]	845	472	566	684	916	764	580 [c]	720
1968	600 [c]	545	630	394	699	662	815	570 [c]	681
1969	600 [c]	645	491	490	696	771	823	580 [c]	705
1970	600 [c]	604	513	382	656	735	790	665	672
1971	600 [c]	585	571	428	676	734	834	599	701
1972	600 [c]	602	569	406	543	653	777	524	650
1973	600 [c]	618	441	308	519	612	844	512	620
1974	600 [c]	521	540	402	577	636	882	522	635
1975	305	684	548	323	740	681	1,018	475	689
1976	550	710	537	477	552	630	1,020	411	683
1977	414	678	521	412	491	665	900	427	648
1978	735	748	529	499	465	639	835	444	641
1979	380	681	592	444	388	670	1,020	419	684
1980	277	531	555	454	424	617	1,233	456	705
1981	536	661	571	415	337	744	1,171	522	715
1982	285	630	557	398	373	498	1,268	527	679
1983	207	523	565	404	374	468	1,184	460	637
1984	191	464	557	257	216	325	1,060	619	533
1985	782	825	783	437	587	861	959	690	784

[a] Total rounded to nearest 100,000 tons before 1970, and to nearest 10,000 tons from 1970 to 1974.
[b] Total rounded to nearest 100,000 hectares before 1970, and to nearest 10,000 hectares from 1970 to 1974.
[c] Estimated.

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Table B-3
Population

Million persons
(except where noted)

	Mauritania	Mali	Burkina	Niger	Chad	Sudan	Ethiopia	Somalia	Total
1960	1.0	4.1	4.4	2.9	3.1	11.8	22.0	2.0	**51.2**
1965	1.1	4.5	4.9	3.5	3.4	13.5	25.0	2.5	**58.4**
1970	1.3	5.7	5.1	4.1	3.7	13.9	29.0	2.8	**65.5**
1975	1.4	6.3	5.6	4.7	4.0	16.0	33.5	3.1	**74.6**
1980	1.6	7.0	6.2	5.3	4.5	18.7	38.0	4.6	**85.9**
1985	1.9	8.1	6.9	6.1	5.0	21.6	43.0	5.6	**98.1**
1990 [a]	2.1	9.2	7.8	7.2	5.7	24.8	50.1	6.3	**113.2**
Expected annual growth, 1985-90 (*percent*)	2.6	2.8	2.4	3.3	2.5	2.9	3.1	2.4	**2.9**

[a] Projections.

Sources: FAO Production Yearbooks, 1965-85; 1984 Ethiopian census; World Bank, *Toward Sustained Development in Sub-Saharan Africa*, 1984.

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Appendix C

Estimating Grain Production [6]

Historical data show that grain yields in the eight countries included in this study are very much influenced by precipitation. To estimate grain production for the three weather scenarios, we derived simple relationships between yield and precipitation for each country over the 1961-85 period. Correlation analysis showed good correlations between all-grain yields and precipitation during the vegetative period (July-August), the flowering and late periods (August-October), and total annual precipitation in five of the eight countries surveyed. No such correlations were evident for Burkina, Somalia, and Ethiopia where grain yields have been increasing even though precipitation has been decreasing during the last 25 years.

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To project grain production, we derived linear regression equations between all-grain yields and average annual precipitation for the agricultural areas of each country surveyed (table C-1). The upward time trends estimated in the yields for Ethiopia and Burkina reflect the effects of increased fertilizer use (Ethiopia) and movement of agriculture into more fertile river valleys (Burkina). Somalia showed no significant relationship between rainfall and yield—possibly because of the insufficient number of climatic stations.

Tests of the linear regression equations showed that they provided a reasonable basis for linking rainfall to achievable yields. This was especially true when focusing on five-year averages or regional totals. For

Table C-1
Equations Linking Grain Yield and Precipitation, 1961-85 [a]

	Equation Constant (a)	Precipitation Coefficient (b)	Time Coefficient (c)	R^2
Mauritania	23.4	1.635	0	0.491
Mali	140.0	0.809	0	0.512
Burkina	−670.2	0.489	11.13	0.594
Niger	148.7	0.608	0	0.630
Chad	−272.2	1.168	0	0.528
Sudan	−147.5	1.958	0	0.695
Ethiopia	−1,717.5	0.486	28.83	0.779

[a] The estimated equations had the form:

$Y = a + (b \times P) + (c \times T)$ where,

Y is all-grain yield for specific country in kg/ha.
P is total annual precipitation for agricultural areas of specific country.
T is the year.
a, b, and c are coefficients estimated from the historical data.
R^2 is the coefficient of determination, which is a rough measure of the share of the variation in yield explained by the equation.

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[6] Additional details on the techniques used to estimate grain production and future precipitation levels are available on request.

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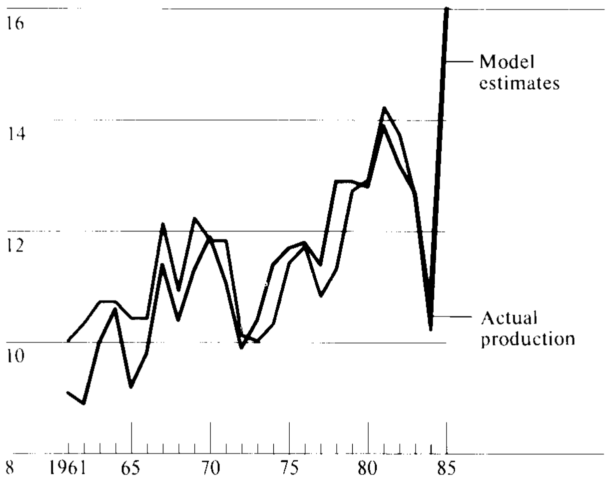
Figure 9
The Sahel and the Horn:
Estimated and Actual Total Grain Production, 1961-85
Million tons



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example, figure 9 shows the excellent performance of the equations in tracking regional grain production during the 1961-85 period. 25X1

Projections for Ethiopia and Somalia required special considerations. Although rainfall had a significant impact on yield in Ethiopia, the time trend was much more important. Yields have been increasing at a trend rate of about 24 kg/year during the last 25 years, probably because of the increased use of fertilizers and the elimination of less productive land. There has been no such increase, however, since 1979, probably because of the internal turmoil and civil war. Taking into consideration these changes and the disruptions expected from the resettlement and villagization programs already under way, we adjusted the time trend down significantly in our projections. In the case of Somalia, where there was no useful statistical relationship, we used the average yield of the last 10 years for the most likely scenario, and the highest and lowest five-year yields over the same period for the best and worst case scenarios. 25X1

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Appendix D

Future Precipitation Levels

Two statistical techniques—the SPECTRA and ARIMA procedures of SAS computer software—were explored for forecasting precipitation levels in the region of northern Africa that includes the eight countries of this study. Both techniques were used to analyze the regional precipitation time series (1921-85) and to project the series into the 1986-90 period.

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The SPECTRA procedure performs a spectral analysis on the time series and determines the presence and relative importance of cyclical variations in precipitation. The results of the spectral analysis confirm that the overwhelming characteristic of the recent rainfall regime is the downward trend observed since the 1960s. Because of the limited length of the series (65 years), the procedure cannot determine whether this downward trend is part of a longer cycle. The analysis did detect weak cycles at about 11 to 13 years, 6 years, 3.5 to 4 years, and 2.4 years, but the cycles could not be reliably used to forecast precipitation.

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The ARIMA procedure—the autoregressive integrated moving-average model—develops a predictive equation for rainfall through an iterative technique and was chosen to develop the most likely precipitation forecast in the study. The technique selects the coefficients of the model that minimize the differences between the historical precipitation data and values derived by the predictive equation. We estimated various forms of ARIMA models for the years 1921-75 and tested them against data for 1976-85. Table D-1 includes the forecast of the preferred ARIMA model for the 1986-90 period. The ARIMA method provides the preferred model for forecasting the precipitation regime for the next five years, but it cannot account for any long-term cycle that might exist. Nevertheless, by giving greater weight to the most recent episodes, the ARIMA method does appropriately consider a significant characteristic of climate—when changes do occur, they occur relatively slowly, and the best indicator of the immediate future is the immediate past.

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Table D-1
Precipitation Forecasts and Probabilities [a]

Scenario	Annual Average Regional Precipitation *(millimeters)*	Probability of Precipitation Being Equal or Lower *(percent)*
Worst	421	40
Most likely (ARIMA)	432	50
Best	601	99

[a] The probabilities for the best and worst case scenarios were estimated by comparing the best and worst case precipitation levels with the confidence band around the most likely precipitation level estimated by the ARIMA method.

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