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May 1988

# World Agriculture

## Situation and Outlook Report

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Reprint

**Third World Agriculture and  
U.S. Agriculture Interests**

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## INTRODUCTION

Most developing countries are becoming more dependent on grain and oilseeds imports from developed countries. This dependence does not necessarily stem from a failure to develop their economies. The opposite appears to be true. While economic rates of growth vary tremendously among developing countries, the major reason for the growing import dependence of developing countries seems to be economic growth and development.

This special issue of *World Agriculture Situation and Outlook Report* reprints a number of recent articles on the topic of how agriculture in what has come to be known as the Third World affects U.S. agricultural interests. The first three articles discuss policy issues, including the world debt problem and government intervention in agriculture. The next three articles discuss world demand and trade patterns. The final four articles focus on how world trade in wheat, corn, sorghum, and soybeans is affected by production and utilization in developing countries.

No two countries develop the same way, but most countries follow the same general pattern. At an early stage, the majority rural population provides adequate food for itself in aggregate (this may not hold true, strictly speaking, on a household level, since research in many low-income developing countries shows that most rural households are net purchasers of food). The small urban population has a sustained but low level of diet heavily weighted to food grains and/or starchy roots and tubers. At a later stage, increasing investment in inputs like fertilizer and small-scale technology results in a surplus of agricultural production, and diet becomes more diversified as a result of rising income. In terms of per capita income, countries that have reached this transition usually rank as middle-income countries.

As the process of development moves ahead, output by the agricultural sector continues to grow, while labor moves from agriculture to industry. Diet diversification accelerates, changing in the middle- and high-income developing countries away from reliance on food grains and roots/tubers to include a larger component of animal products like meat, eggs, and dairy products. At this point, demand for food is likely to outstrip a country's ability to produce food, even at a high rate of growth. Moreover, availabilities of productive resources and range in climate become limiting. Food imports to fill the resulting gap drive down self-sufficiency ratios, particularly for coarse grains needed to support an indigenous livestock sub-sector.

U.S. farmers face an interesting trend in developing countries. With demand in high-income developing countries outpacing domestic production, the volume of world agricultural trade has increased greatly since World War II. But when attention focuses on a handful of countries that have succeeded in developing a comparative advantage in an agricultural product that competes directly with U.S. exports, the overall trend of trade expansion is lost sight of. Such cases do raise difficult policy choices for Americans, but most developing countries' exports do not threaten U.S. farmers' markets. More recently, the debt burden carried by some high-income developing countries has had a negative effect on their capability to import agricultural products.

As the following articles demonstrate, the United States stands to gain from helping developing countries move to higher income levels.

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## DOMESTIC POLICIES YIELD INTERNATIONAL CONSEQUENCES

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**Abstract:** The world has large surpluses of cereal grains in many of the industrial-market countries and low international prices as exporters compete fiercely for markets. Many developing countries could be growing markets for cereal grains if their economies prosper. In most developing countries this will require a dynamic and growing agriculture. Long-range plans to expand developing country imports should include agricultural sector support.

**Keywords:** Agricultural development, agricultural trade, agricultural policies.

Agriculture is a global industry in which a country's domestic actions have international effects. Agricultural policies, implemented by one country to help solve its domestic agricultural problems, affect not only that nation's own trade, but trade among other countries as well. Broadly speaking, many industrial market countries apply policies to reduce the pain of agricultural adjustment to economic development or other changes, and also to insure a national food supply in an international crisis. These policies have contributed to a buildup of grain stocks in some of these industrial countries and to low grain prices worldwide.

Farm commodity prices are very low in international markets. Surplus stocks have reached records, yet current production for many commodities still exceeds use. Production incentives provided by industrial-market governments, which respond too slowly to changing international markets, are largely the cause of current surpluses. Costs of farm programs in the United States, EC, and Japan have reached very high levels, with rising farm subsidies, storage expenses, and export subsidies.

However, these problems are not caused by agricultural policies alone. Other factors have interacted to make these problems more severe. These factors include a slowdown of imports by centrally planned countries, the world recession of the early 1980's, and the debt crisis in the developing countries.

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1/ Numbers in parentheses refer to sources listed at the end of the article.

Much of the current concern about agricultural policy and international trade centers on imbalances between production and demand growth in the industrial-market and developing countries. In many industrial market countries, demand is growing slower than production, creating surpluses. Much of this output is subsidized (1, 8) 1/, keeping excess capacity in production. The developing countries are becoming more dependent on agricultural imports, because rising incomes have allowed consumption to grow more rapidly than production.

### *Industrial Economies Boost Output*

The industrial-market countries commonly use prices and other policy measures to support farmers' incomes and slow the migration of people out of agriculture. When domestic support prices are fixed above international market-clearing prices, excess land, labor, and capital are kept in production, often leading to surpluses. These surpluses have to go into storage (often government-owned) or are exported using subsidies.

Relief from current surpluses in the United States and other industrial market countries is unlikely to come from growth in domestic demand. In the EC, for example, agricultural production has been rising almost 2 percent a year since the late 1960's. However, EC consumption has been rising only about .5 percent (3). During this time, the EC switched from being a major net importer of cereal grains to being a major exporter. This dramatic shift resulted in the loss of a large



market for U.S. farmers and more competition for markets in the developing countries.

In the high-income, industrial-market societies, the output of many basic food commodities increases faster than consumer demand. Their consumers do not want a greater physical quantity of food; increases in consumer expenditures with rising incomes in high-income countries are for variety, improved quality, and more processing and retailing services with food. Agricultural productivity, however, continues to advance with the introduction of new technology.

The cost advantages of this new technology often require larger farms, thus substituting capital for farm labor. This substitution is a long-run characteristic of agriculture under economic growth (4). To slow the exodus of people from agriculture, policymakers in the United States, as well as in the other industrialized countries, have often supported agricultural incomes with price support schemes.

If price supports are set above international prices, import restrictions or tariffs are required when the supports create incentives to import protected commodities (such as sugar in the United States), and export subsidies are needed when production exceeds domestic use and the government does not want to store the surplus (such as wheat in the EC).

Export subsidies directly affect the trade performance of other countries and can force them to adopt offsetting policies. For example, the EC's export subsidies enabled it to take foreign markets away from other exporters. The United States recently modified its policies and programs in an attempt to regain lost market share. The U.S. Food Security Act of 1985 is intended to make U.S. agriculture more competitive by reducing price-supporting loan rates. Also, a variety of export programs are authorized, including the Export Enhancement Program, which uses CCC stocks directly to counter subsidized EC exports in specific markets.

The stagnation of the world grain market since the 1980-82 world recession has led to a

sharp buildup of world and U.S. grain stocks. Ending stocks of the major world wheat exporters for 1986/87 are estimated to be 82.5 million tons, with the United States holding nearly two-thirds. To put this amount in perspective, the U.S. holdings equal about 2 years of U.S. consumption. The United States will have nearly three-fourths of the world's coarse grain stocks by the end of 1986/87, close to 1 year of U.S. consumption, and more than three times the forecast volume of U.S. exports in 1986/87.

With the buildup of such large stocks, more attention is being given to the factors underlying the rapid growth of the developing countries' agricultural imports during the 1970's and the slowing of this growth during the early 1980's.

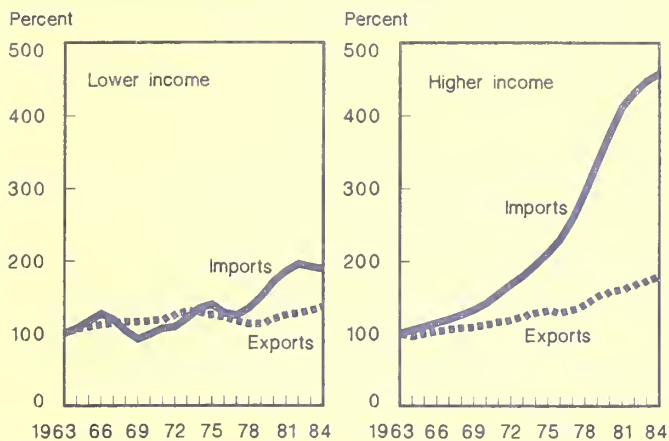
### *Third World Debt Limits Imports*

A major source of agricultural import growth during the past two decades has been the developing countries. Developing countries' effective demand for food exceeded their production during the 1970's because of rapid economic growth. The growth in agricultural import markets was especially rapid among the less developed countries (LDC's) with higher incomes. 2/ However, agricultural imports by these higher-income developing countries slowed with the 1980-82 world recession and the Third World debt crisis. The debt crisis has placed the economic prospects of many developing countries in jeopardy.

2/ The World Bank classifies developing countries into four categories based on annual per capita income: low-income, lower-middle-income, upper-middle-income, and high-income oil-exporters. The low-income and lower-middle-income countries, excluding the People's Republic of China, are considered here as lower-income developing countries and the remaining two categories as higher-income developing countries. The lower-income countries include 2 billion people with per capita incomes ranging from \$100 to \$1,700. The higher-income countries include .5 billion people with per capita incomes greater than \$1,700 (8).



## Agricultural Trade in Higher- and Lower-Income LDC's



Percent of 1961-63 average using deflated 3-year averages.

Foreign debt accumulation in developing countries accelerated in 1973-74 as higher oil prices sharply increased trade deficits in oil-importing developing countries. These deficits were financed through loans with low interest rates as banks recycled the oil earnings of the petroleum-exporting countries. Because of the low interest rates, many developing countries (including some oil exporters such as Mexico and Venezuela) borrowed heavily to finance investments to accelerate their economic growth. Between 1974 and 1979, the economic growth rate of developing countries was double that of industrial countries.

The 1979-80 increase in oil prices, along with a sudden tightening of U.S. monetary policy to combat inflation, contributed to a severe worldwide recession. Industrial countries' demand for developing countries' products dropped, and commodity prices declined. Export earnings of developing countries deteriorated, reducing their ability to pay their debts. Because many developing countries had short-term loans with variable interest rates, the sharply rising interest rates and strengthening value of the dollar of this period compounded their difficulties. The ability of developing countries to pay their debts deteriorated seriously between 1980 and 1982, resulting in the debt crisis (5).

The international banks then curtailed their lending. Developing countries are now paying more on old loans than they are getting in new loans. This trend is most striking in Latin America, where debtor countries have

paid out almost \$100 billion since 1982, about as much as they received in net lending from 1974 to 1981 (2).

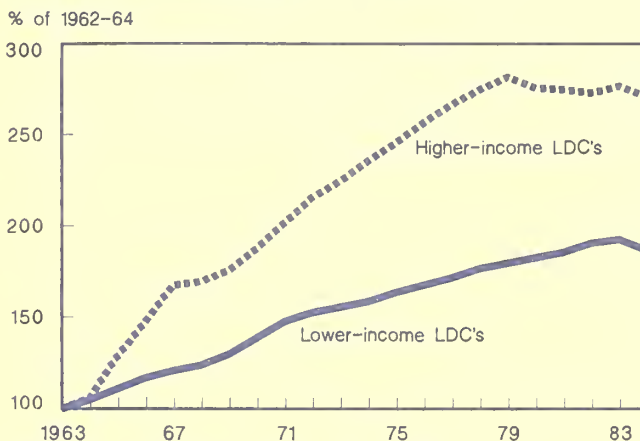
The debt crisis limits agricultural imports in developing countries because debt payments and imports compete for available foreign earnings. Unless countries are able to increase their export earnings or obtain additional long-term loans, they must defer, reschedule, or default on their debts, or else reduce imports. Many countries have reduced their imports. In addition, developing countries that are restructuring their debts are subject to International Monetary Fund conditions that often include policy changes to reduce costly food subsidy programs and realign exchange rates. While these policy changes may reduce food imports in the near term, in the long run they will help countries resume the steady economic growth that leads to increased food demand and imports.

A reduction in trade barriers would help the developing countries export more products to industrial countries and, in turn, buy more agricultural goods. Economic growth due to rising productivity remains the long-term solution to increasing trade, but the debt problems of developing countries will severely limit agricultural imports in the short and medium term unless a way is found to make debt more manageable.

### *Agricultural Development Boosts Imports*

Because agriculture is the largest sector in most developing countries, this sector must

### **Agricultural GDP Growing Faster in Higher-Income LDC's**



Three-year deflated averages centering on dates shown.

be growing if the LDC's national economies are to prosper. For this reason, agricultural incomes and agricultural imports usually rise together in developing countries. In fact, during the 1970's, agricultural GDP was increasing most rapidly among the higher-income developing countries that were increasing their agricultural imports so rapidly. It is this potential for growing export markets that needs to be understood when the United States and other industrial market countries consider their development assistance policies and programs for low-income countries.

Rising productivity increases incomes of farmers and rural laborers. Employment and income in rural and urban areas then rise as farmers spend their higher incomes on goods and services produced off the farm. By increasing the productivity of the land and labor, new agricultural technology can initiate broad-based economic development leading to industrialization and rising per capita incomes. Rising incomes create food demand that eventually outpaces growth in agricultural production, which is why developing countries became more dependent on imports of food grains and coarse grains during the 1970's (7). The increase in trade reliance was not due to declining production; rather, it was due to rising consumption based increasingly on imports supported by rising per capita incomes (6).

The long-run future for agricultural exports of the United States and other countries depends on the prosperity of the low-income developing countries. Development assistance from the United States and other donors should include support for agriculture. While not always successful, improved agricultural technology (and domestic government policies favoring its use) has produced sustained agricultural development in a number of Asian and Latin

American countries, helping them achieve the rapid increases in national growth that lead to increased agricultural imports.

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## THIRD WORLD DEBT AND U.S. AGRICULTURAL TRADE

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**Abstract:** World debt has become an increasingly serious constraint to growth in world trade. The rate of gross domestic capital formation has declined, threatening many developing countries with economic stagnation. Prospects for significant renewed trade with debt-impacted countries are likely to remain bleak for the rest of the 1980's.

**Keywords:** International debt, trade, agricultural trade, monetary policy, financial constraints, monetary transmission, interest rates, exchange rates.

World debt is the most serious constraint to world trade and development in the 1980's. It is a highly intractable problem which could plague the world economy for years to come. The resolution of this problem is one major precondition for the return of a normal world trading environment. Although current strategies under discussion and implementation are likely to begin reducing this constraint, we are still a long way from a solution.

Third World countries are increasing their production of food, but with rising populations and growing per capita consumption, food use is climbing faster than production. This would brighten prospects for U.S. agricultural exports if sustainable economic growth generated the revenues to pay for increased food imports and to meet debt payments at the same time. However, in spite of the recovery from the world recession of 1981-82, the debt repayment problem is constraining these countries' agricultural imports. Export promotion and credit policies are, however, helping the United States recapture part of the market lost since the early 1980's. The policy of responding to a financial crisis with financial solutions appears, therefore, to be one way for the United States to maintain its market share of key export commodities.

### *Oil Shocks, Easy Money Set Stage For Debt Repayment Problems*

The oil shock of 1973-74, combined with the development of well integrated international capital markets, began the process by which debt was accumulated. The fourfold increase in petroleum prices initiated

by the Organization of Petroleum Exporting Countries (OPEC) threw many developing countries into substantial trade deficits. The response of the developed countries was to accommodate the oil increases by adopting easy monetary policies. Against this, the huge profits generated by the upper-income oil exporters led to enormous dollar deposits in international banks. International bankers began a massive lending program to the developing countries to recycle the "petrodollars." The longer-term effect of the oil price increase was significant debt accumulation by developing countries, setting the stage for the current world debt problem.

The world economy weathered the first oil crisis without much difficulty. Initial debt levels were low enough that accumulation did not overly burden the world payments system. Furthermore, the infusion of large amounts of international capital into the world economy generated an international expansion led by export growth. For all non-OPEC developing countries, the total dollar value of exports was 2.5 times greater in 1980 than in 1975. Furthermore, annual real growth in gross domestic product (GDP) for all developing countries averaged 5 percent during this period.

The second oil shock of 1979-80 set the stage for the world recession of 1980-83. The second petroleum price increase was more significant than the first because of the large debt that had accumulated and the far different policy response of the industrial nations. In 1979-80, the major industrial countries immediately restricted available credit. This lowering of monetary growth



sharply slowed the world economy, raised real interest rates, and made the debt burdensome. The developed countries' response to the second oil shock triggered the current repayment problems.

### *Role of International Capital Markets*

If the oil price shocks of the 1970's led to changes in the monetary policies of the industrial countries, the growing world integration of capital markets transmitted the changes from lenders to borrowers, and magnified the growth of international credit availability.

Market interest rates have grown in importance in loan repayments, particularly since 1978-79. Loans extended at variable interest rates, with premiums at fixed points above the U.S. prime rate or the London Interbank Offered Rate (LIBOR), became popular during the late 1970's.

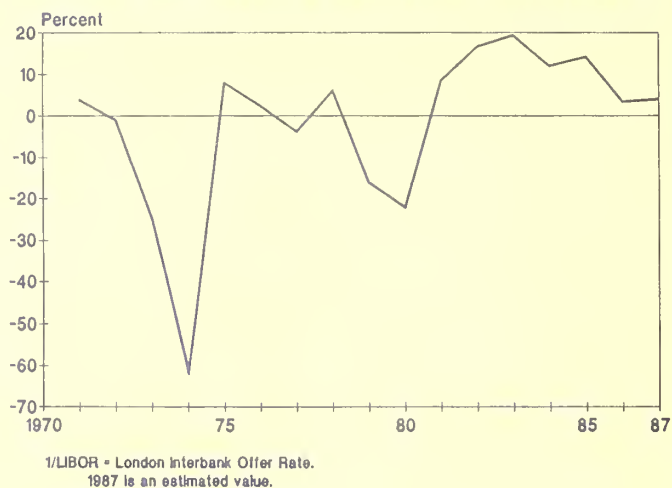
### *Changes in Interest Rates*

Real interest rates, incorporating price changes, provide a measure of the current opportunity cost of debt repayment. The appropriate measure for debtor countries is the interest rate adjusted for changes in export prices. The effect of the rapid increase in world liquidity is very evident when considering the real interest rates faced by the developing countries. The decade of the 1970's was dominated by price increases far in excess of the nominal interest rate.

That situation quickly reversed itself in the 1980's. Nominal long- and short-term interest rates on dollar loans rose sharply beginning in 1978, as rising inflation began to add premiums to the cost of borrowing. Not until 1981, however, did price increases fall below interest rates, and the real rate then increased sharply. Despite the decline in short-term rates in 1983-85, real interest rates facing all developing countries remained above 10 percent, and were higher in 1985 than in 1984. Only in 1986 and 1987 did real interest rates fall to below 4 percent.

The debtor nations were therefore caught in a difficult situation. The principal on loans that had been falling in real value began to rise at an accelerating rate. The declining

**Figure 1**  
**Real interest rate, Developing countries:**  
**6-month LIBOR less change in export unit values 1/**



real repayments so evident and welcome during the 1970's also began, in 1981/82, to rise in real value.

### *Commodity Prices Fall*

The trend of export prices received by developing countries also changed substantially between the 1970's and 1980's. The real appreciation of the developing countries' currencies during the 1970's, and general raw material shortages, contributed to price increases. Those factors were reversed in the 1980's as export promotion (real devaluation) policies accompanied excess stocks of primary, raw commodities important to lower- and middle-income countries. Price changes directly reflect the sharply different exchange rate, interest rate, and monetary environment of the 1980's compared with the 1970's. Between 1973 and 1980, non-oil commodity export prices more than doubled. Since 1981, however, these prices have declined approximately 25 percent. Only in 1987 is there any indication of renewed increases in some commodity prices.

### *Rescheduling Indicates Debt Problem*

Before the 1980's, debt repayment problems did not pose a serious threat to the world economy. From 1956 to 1980, only 22 countries rescheduled about \$21 billion. The pattern of international debt reschedulings since then indicates a serious misalignment between payment commitments and the ability of countries to service their debts.

Reschedulings have been escalating continuously, from \$55 billion in 1981-83 to \$93 billion in 1985 and \$122 billion in 1986. The magnitude of the reschedulings is a clear indication that the problem is getting worse.

At the same time that the problem for the developing countries seems to be getting worse, the risk to commercial banks appears to be abating. At the peak of the crisis in 1982, loans to developing countries by major U.S. banks amounted to more than twice bank capital. However, by March 1987 this ratio had declined to almost 1 to 1.

### *Credit Withdrawal Begins in 1983*

Although total debt continued to increase into 1987, there has been a pronounced withdrawal of credit since 1983 because the growth of debt has been less than interest payments. The annual growth rate of debt exceeded 20 percent during 1973-81 for all developing countries, but there has been a clear secular decline since 1978. The Northeast and Southeast Asian countries had among the highest growth rates of debt over the 1973-83 period, but of the East Asian groups only the Philippines has experienced debt payment difficulties. 1/

This situation strongly suggests that rapid accumulation of debt does not have to lead, in itself, to subsequent debt servicing problems. If credit is used to make investments which generate foreign earnings in excess of payment requirements, then even large debts can be serviced. But if the credit is used to expand consumption, payment difficulties will arise. Difficulties will also occur for investments with either lower rates of return in foreign earnings than restitution due or a pattern of returns which does not match repayments.

The withdrawal of credit to developing countries, indicated by the declines in the growth of debt, is magnified when one considers the net flow of credits to developing countries during 1973-86. Between 1974 and

1982 the cumulative net inflow of credit to developing countries equaled about \$200 billion. In 1978, net inflows peaked at \$57 billion. Starting in 1983 and continuing through 1986, there was an outflow of credit of about \$100 billion. This change in credit availability is mirrored in international trade patterns. Imports of developing countries declined by almost \$100 billion a year from the peak.

### *The Consequences*

The process of adjusting to the overaccumulation of debt in the 1970's has had several major consequences. For the developing countries, there has been, first and foremost, a decline in per capita income growth. This has been the direct result of policies to constrain imports, at least partially by inhibiting aggregate demand. Imports have also declined, a consequence of trying to control balance-of-trade deficits. This reduction was a major feature of the adjustment observed since 1982. However, exports have not grown as expected, partly because of reduced income growth in the developed countries.

Renewed growth in the developing countries implies investment in new industries, or in existing export industries to sustain export growth. The withdrawal of credit has been accompanied, and paid for, by reducing gross domestic capital. The ability to generate renewed growth in developing countries is predicated on their capacity to increase exports. Therefore, if substantial numbers of countries are simultaneously reducing their capital formation as well as their imports, increased export sales become extremely difficult, as has been the case since 1982.

Although many countries have been adjusting their current account balances, no evidence of renewed growth appears to be following. The adjustments to the debt crisis may well have forced developing countries (and, possibly, the world economy) into a low-level growth equilibrium. This situation will prevent the rapid reduction in the debt ratios which would lead to new credit availability and growth in the developing countries. Because these countries have been growth markets for U.S. agricultural exports, the main effects of the debt crisis have been

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1/ Northeast Asia comprises Hong Kong, South Korea, and Taiwan. Southeast Asia comprises Indonesia, Papua New Guinea, Malaysia, Philippines, Singapore, and Thailand.



to constrain world trade in general, U.S. agricultural exports in particular, and the agricultural portion of total trade.

One of the most pronounced features of 1970-85 was the increase and subsequent decrease in the rate of gross domestic capital formation. For all developing countries, the rate averaged just over 23 percent during 1970-74, 27 percent during 1975-78, 26 percent during 1979-82, and 24 percent in 1984-85. The decline is most pronounced in the Latin American region and among the debt-affected major borrowers. The fall in gross domestic capital formation is evident in all of the groupings except Asia, where the very high rates achieved in the middle of the period were exceeded by the end of the period. This decline is one of the more pessimistic outcomes of the debt adjustment process.

### *Agricultural Trade*

Agricultural trade patterns generally follow trends similar to those of merchandise trade. Historically, agricultural trade is becoming less important in total trade. In times of stress, however, agricultural imports get preference over other imports.

Agricultural imports increased after 1982 compared to all imports by developing countries, rising to 15 percent of the total in 1984 from 13 percent in 1982. The most substantial increase was in Sub-Saharan Africa, where agricultural goods increased as a proportion of all imports since 1976. The most dramatic case of agricultural imports substituting for other imports was in Latin America. Agricultural products rose to 15.5 percent of all imports in 1984, up from 11.5 percent in 1982, higher than at any time during the 1970's. Only Northeast Asia sustained the trend of agricultural imports falling as a proportion of all imports. Major U.S. markets showed an upward trend in purchases of farm products in relation to all goods in 1982-84, up from 13 percent to 15 percent.

### *U.S. Agricultural Exports*

The value of U.S. agricultural exports to developing countries fell sharply in 1982, recovered in 1983 and 1984, and plummeted again in 1985 and 1986. The total dollar amount in 1986 was only slightly above that of

1979. No grouping of countries imported a higher dollar value of agricultural products from the United States in 1986 than in 1984.

The U.S. market share through 1984 remained above the levels of the late 1970's, except in 1982. Market share gains were confined to declining markets, however. U.S. farm products accounted for 50 percent of those in Latin America, up from 35-45 percent in the late 1970's. The United States maintained a larger proportion of total agricultural product sales in major agricultural markets, but has not been very successful at competing in the potentially expanding Asian markets. Factors other than the debt problem probably are more important in explaining this.

### *Measures to Resolve the Debt Problem*

The preferred world scenario for resolving the debt crisis would include a period in which debt-affected countries would undertake policy changes to realign their export-import balance, followed by a period of renewed world growth led by expansion of trade. However, there is no evidence of this actually occurring.

Except for North Africa and the Middle East and South Asia, the needed adjustment to the change in finance availability has taken place, but there is scant evidence that this adjustment will be followed by renewed income and trade growth. Commodity prices have fallen and, partly due to the need of debt-impacted developing countries to generate increased export earnings, may stay down for the foreseeable future. Additionally, the global effect of contracted imports and export promotion in such a large part of the world has led to a situation in which the export markets have become more competitive and more constrained.

Solutions to the debt crisis to date have served to maintain the present value of developing-country debt. Rescheduling debt has become commonplace, with the effect of superficially improving the term structure of the debt but not of reducing its burden. Many of the debtor countries find themselves in a situation where the debt load is equal to or greater than it was at the start of the debt crisis in 1982. For all of the adjustments and renegotiations, the constraint which debt has



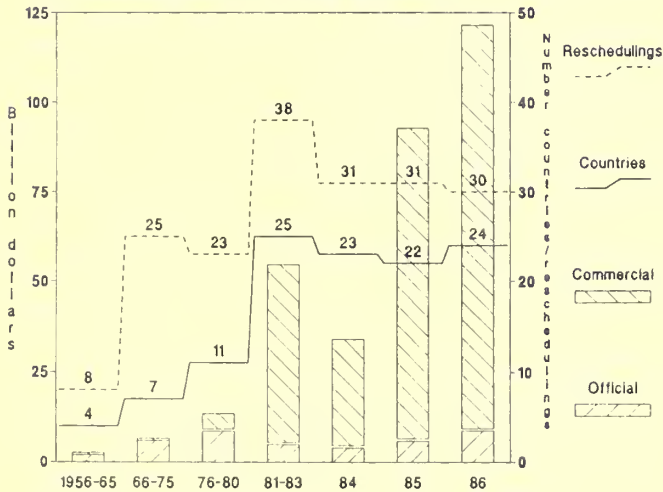
imposed on world trade and development has not been noticeably reduced.

Recently, measures aimed at reducing the burden of debt have been suggested and, in fact, been implemented in some countries. Debt-for-equity swaps and secondary markets for developing-country debt are part of the newly suggested measures. Other proposals call for loan writedowns and/or writeoffs. The reduced exposure of commercial banks to developing-country loans and the increases in loan loss funds by commercial banks also imply that financial institutions are now better prepared to consider this option than in recent years.

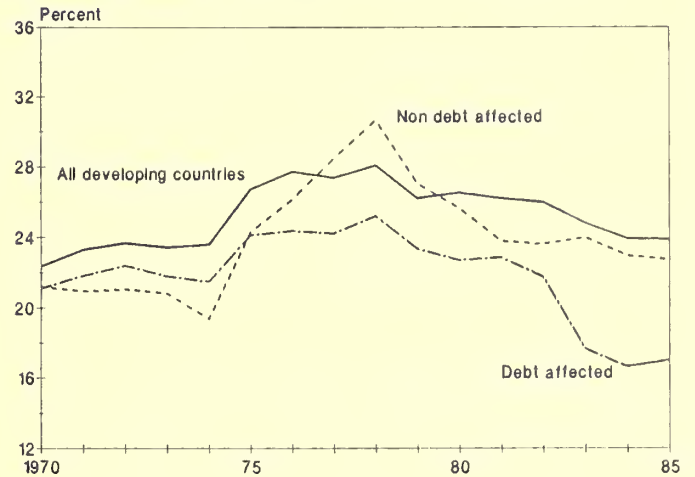
While these suggested measures hold the promise for significant reductions in the debt burden and the financial constraint on trade, potentially serious questions arise with respect to the costs of writedowns and how these writedowns will be shared between developing countries, financial institutions, and developed countries.

Of course, the long term success of any efforts to reduce the debt burden of developing countries will critically depend on whether these countries are prepared to undertake serious economic adjustments and to reduce direct government interventions in their economies so that future resources will be invested in areas which have the highest potential for returns in an open world economy.

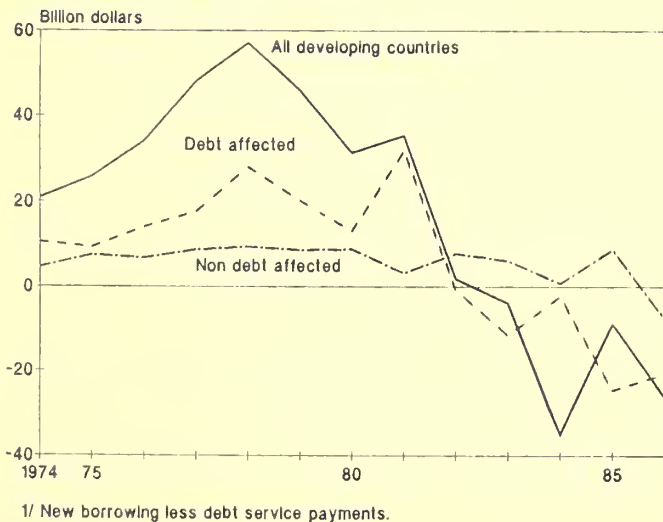
**Figure 2**  
Debt reschedulings, number of countries rescheduling, and type of debt



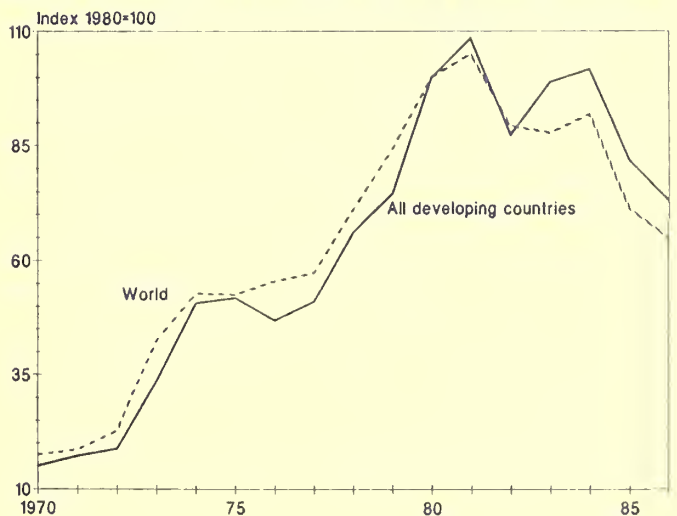
**Figure 4**  
Gross domestic capital formation as a share of gross domestic product



**Figure 3**  
Net flow of credit 1/



**Figure 5**  
U.S. exports to the world and developing countries



Editor's Note:

A number of small changes have been made in the original text and tables of this article by Ballenger and Mabbs-Zeno to incorporate analysis of data through 1986.

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GOVERNMENT INTERVENTION IN AGRICULTURE:  
THE CASE OF DEVELOPING COUNTRIES

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**Abstract:** Developing countries play an increasingly important role in world agricultural trade, and they represent growth markets for agricultural exports. In spite of this, their role in current trade negotiations has not been clearly defined. This article examines the nature and implications for world trade of government intervention in agriculture in developing countries.

**Keywords:** Developing countries, less developed countries (LDC's), agricultural trade, subsidies, PSE's.

The importance of agriculture in the current round of multilateral trade negotiations offers an opportunity for developing countries (LDC's) to participate more fully in negotiations than ever before. The priority attached to agricultural trade issues encourages LDC participation because agriculture's role is more important in many developing economies than in industrial market economies (IME's). Primary commodity exports other than fuels, minerals, and metals accounted for 21 percent of all LDC exports in 1985. These same exports were only 13 percent of IME exports. In Argentina, agricultural exports comprised about 77 percent of total exports in 1985, while in Brazil they were about 44 percent. Value of agricultural production accounted directly for 20 percent of gross domestic product (GDP) of LDC's in 1985, and only 3 percent in IME's (16). 1/

1/ Numbers in parentheses refer to sources listed at end of article.

Some sectors in LDC's could gain from negotiations aimed at reducing agricultural trade barriers and subsidies in a number of ways. If negotiations lead to lower import barriers for agricultural commodities, LDC exporters will have greater access to IME markets. If negotiations reduce subsidization of agriculture, particularly exports, LDC's may face less competition in agricultural export markets. For example, the European Community (EC), due to its system of farm supports, has switched from being a major importer of Argentine beef to being a major competitor in the beef export market. Reducing protection to agriculture on a world basis would result in generally higher international commodity prices (9, 10, 11). 2/ For LDC agricultural exporters, these price

2/ Protection raised prices domestically in IME's, reducing domestic consumption and passing increased production onto international markets.



impacts could translate into substantially higher foreign exchange earnings (17). For LDC farmers, these price impacts could translate into higher incomes, providing a stimulus to general economic growth.

Agricultural importers in LDC's may view the potential impacts of trade negotiations in a less positive light than agricultural exporters. If protection of agriculture in IME's has depressed world prices, then these policies have subsidized LDC food imports. Nonetheless, many LDC's that depend heavily on food imports also have large agricultural sectors that have been adversely affected by low world prices. Persistently low world prices may have harmed LDC agricultural growth rates (and, consequently, economic growth rates) and made it prohibitively expensive for some countries to obtain politically desirable levels of food self-sufficiency. Recent research has shown that the current forms of agricultural support worldwide have contributed to world commodity price instability, making it more difficult for LDC's to predict foreign exchange requirements and availabilities (11).

From the viewpoint of IME's, greater participation of LDC's in this round of agricultural trade negotiations is desirable. LDC's play an increasingly important role in world agricultural trade, and they represent growth markets for agricultural exports (6). Developed countries desire greater access to these markets and should be prepared to make concessions to LDC's in order to obtain it. Furthermore, LDC's are such important traders in many world commodity markets that an agreement not sanctioned by them may not be meaningful and lasting.

Despite the potential importance of LDC's in the trade negotiations, their role has not been clearly defined. This is in part because the negotiating framework for agriculture has not yet been clearly determined. Past negotiations were based on the offer-request framework. Agreements were usually made on a bilateral, commodity-specific basis. The benefits of the concessions were shared with other members of the General Agreement on Tariffs and Trade (GATT) through the most-favored-nation rule. LDC's participated relatively little in this exchange of concessions, instead preferring to seek the

"special and differential treatment" that the GATT allows them (16). In obtaining special and differential treatment, LDC's were not required to extend reciprocal concessions to IME's but, consequently, IME's were less interested in offering concessions to LDC's. Agreements in earlier rounds benefited principally the United States, Japan, and the EC (5).

The current round of agricultural trade negotiations could proceed along very different lines. Many countries, led by the United States, have expressed an interest in an across-the-board agreement that would limit all government support to agriculture through reducing trade barriers and limiting all subsidies, both direct and indirect, that affect agricultural trade (4).

The possibility of a multilateral agreement such as that suggested by the United States raises a number of questions about LDC participation. Should LDC's be required to roll back their own support to agriculture at the same time and to the same degree as IME's? Should higher-income LDC's participate to a greater degree than lower-income countries? How should intervention in agriculture be handled in the context of the negotiations where it taxes producers? How different are the implications of agricultural policy reform in LDC's compared to IME's? The importance of agriculture in many LDC's suggests there could be profound political and economic consequences of policy changes.

An examination of the above issues requires an understanding of the nature and implications of government intervention in LDC agriculture. A number of studies have investigated this area, including one by the Economic Research Service (ERS) on trade liberalization that compares producer and consumer subsidy equivalents (PSE's and CSE's) for 16 developed and developing countries and the EC in grain, oilseed, livestock, dairy, cotton, sugar, and selected other commodity markets (12, 13).

A PSE is defined as an estimate of the amount of cash subsidy needed to compensate farmers for the removal of all government support. A PSE can be positive or negative, a negative number implying that the net effect of government programs is to tax farmers. A



PSE for a particular commodity is often expressed as a percent of the value of production of that commodity, facilitating cross-country and cross-commodity comparisons. In contrast to the widely used measure called nominal rate of protection, the PSE framework is designed to capture the producer subsidy component of all forms of government intervention in agriculture, including domestic policies such as input subsidies and trade barriers. Nominal rates of protection indicate only the extent to which trade barriers or pricing policies drive a wedge between prices received by producers (or consumers) and the relevant trade reference prices.

#### *Do LDC's Tax Agricultural Producers?*

The ERS study indicates that a principal difference between government intervention in the agricultures of developed and developing countries is that producer support in IME's is positive, while that in LDC's is negative (that is, it amounts to taxation of agriculture). Other studies support this finding. Nonetheless, it is also clear that support ranges from high levels of positive support in some LDC's to substantial taxation in others. There are also widespread differences within countries among the levels of support to different commodities.

Byerlee and Sain reported nominal protection coefficients for wheat for 31 developing countries for the early 1980's. They found that in 12 of 31 cases the protection coefficients were less than one, indicating that the effect of government intervention in wheat markets was to depress producer prices relative to border prices. When these coefficients were adjusted for the implicit taxation of overvalued exchange rates, 20 of the 31 countries taxed wheat producers (2).

In an earlier study, Bale and Lutz found that nominal rates of protection for wheat, rice, corn, beef, cotton, sugar, and rubber in Argentina, Egypt, Pakistan, and Thailand were negative in all cases except corn and sugar in Thailand (1). The *World Development Report 1986* also reported nominal protection coefficients for a wide range of developing countries in wheat, rice, peanuts, corn, sugar, beef, tea, cocoa, coffee, tobacco, rubber, and cotton markets. Taxation of producers tended

to be higher and more widespread for the traditional export crops, but producer taxation was found in the other commodity markets as well. Several middle-income countries, including South Korea, Portugal, and Thailand, were found to have nominal protection coefficients significantly greater than one for some commodities (wheat and rice in South Korea, beef in Portugal, and sugar in Thailand) (15).

The ERS study includes PSE's for Argentina, Brazil, India, Indonesia, Mexico, Nigeria, South Africa, South Korea, Sudan, Taiwan, and Thailand, although commodity coverage varies by country. The net effect of government programs during 1982-84 was found to tax producers of at least some crops in Argentina, Brazil, India, Indonesia, Nigeria, and Sudan. For some crops in these countries, the PSE's were positive despite policies that taxed producers because policies that provided positive assistance offset the taxing effect. The net effect of government assistance to all commodities was positive in Mexico, South Korea, and Taiwan.

#### *Why Do LDC Governments Tax Agriculture?*

LDC governments tax agriculture for a number of reasons. One reason is revenue generation. For example, in Argentina—where agriculture accounts for 80 percent of foreign exchange earnings—agricultural export taxes account for 15 percent of central government revenues (14).

Another reason is to encourage agricultural processing industries by taxing exports of the raw product. For example, Brazil taxes soybean exports at a higher rate than it taxes exports of soybean products. The export taxes depress the domestic prices of the beans, providing an input price subsidy to the domestic crushing industry. Mexico has also taxed or limited cotton exports to encourage supplies for its domestic textile industry.

A third reason for taxing agricultural producers is to provide low-priced food supplies to urban consumers. This approach has been important in Nigeria, where large food imports were encouraged by a strongly overvalued currency in the early 1980's. Most imports were consumed by wage-earning

urbanites who appeared to control the government's trade policy. An overvalued currency was also an important food policy in Mexico prior to 1982.

### *How Do LDC Governments Tax Agriculture?*

LDC governments tax agricultural producers through a number of mechanisms, explicit and implicit. Border taxes, quotas, and trade licensing requirements are direct techniques used in Argentina, Brazil, Mexico, and Nigeria. Marketing boards that buy crops at lower-than-border prices are found in India, Sudan, and, until 1987, Nigeria.

An important implicit form of taxation is through the official exchange rate system. By fixing nominal exchange rates, many LDC's have maintained overvalued currencies, resulting in lower prices of traded goods (expressed in domestic currencies) than would prevail under more flexible exchange rate regimes. This system taxes producers and subsidizes consumers of traded goods. The ERS study indicates that during 1982-86 an overvalued currency was an important source of taxation in Brazil, Nigeria, South Africa, and Sudan. A major devaluation of the Mexican currency in 1982 produced an undervalued currency and an implicit subsidy to agricultural producers.

### *Do Input Subsidies Offset Producer Taxes?*

Many LDC's assist farmers through subsidies on purchased farm inputs and farm credit. This assistance is sometimes justified because it offsets the negative effects on farm income and output resulting from the tax policies. Farm input subsidies are important in many LDC's, and may counteract the effect of tax policies. In Brazil, the values of production and marketing credit subsidies were important enough to offset (on average) the negative value of export taxes, export quotas, and exchange rate policies. On a crop-by-crop basis, the balance was tipped toward positive assistance for Brazilian producers in the cases of wheat, cotton, poultry, and dairy.

In Mexico, input subsidies were also very important sources of producer assistance. Fertilizer and credit subsidies accounted for approximately 40 percent of the total value of

measured transfers to producers of wheat, corn, soybeans, sorghum, and cotton. In the cases of wheat and cotton, positive assistance through these input subsidies offset the negative effects on producer prices of Mexico's import and export policies. In Thailand, the value of irrigation subsidies to rice producers offset the revenue lost through export taxes, although the policies redistributed value within the sector.

### *Do Food Grain Policies Differ from Export Crop Policies?*

Like the *World Development Report 1986*, the ERS study indicates a tendency for LDC's to treat export crop producers less favorably than import-substitution crop producers. For example, in Nigeria, the highest level of producer taxation as a percent of commodity value was found for cocoa, the country's major agricultural foreign exchange earner. On the other hand, the PSE for wheat, an important import-substitution crop, was positive.

In Brazil, soybeans and beef, major export commodities, were not subsidized due to the combined effects of government programs while the production of wheat and rice, important food imports, was heavily subsidized. PSE's for Mexican commodities were positive during 1982-86. However, the lowest level of support went to cotton, the one Mexican export crop included in the analysis, while the highest level of support was for corn, an import-substitution crop and the staple of the Mexican diet. In Mexico, this pattern reflected the country's interest in limiting its dependence on food imports, particularly corn. India provided positive assistance to producers of high-value products like peanuts and rapeseed and soybean oils. The commodity taxed at the highest level in India was cotton, the one Indian export crop included in the study (8).

### *Do Higher-Income LDC's Treat Agriculture Differently from Lower-Income LDC's?*

Nominal protection coefficients for agriculture are positively related to per capita income. This is because agricultural protection becomes affordable at high levels of per capita income and agriculture is an important source of revenue at low levels of per capita income (7). Middle-income economies like Colombia, Côte d'Ivoire,



Mexico, South Korea, Thailand, and Turkey tend to provide higher price protection (or lower taxes) to their producers than low-income economies like Bangladesh, India, Malawi, Pakistan, and Tanzania (15). Although the ERS study includes only a limited set of LDC's, it lends credence to the theory that support to agriculture increases as countries move up the income scale. Among the LDC's studied, positive levels of producer assistance were found in Mexico, South Africa, South Korea, and Taiwan. South Korea and Taiwan maintain agricultural trade policy regimes similar to Japan's highly protective system (3). Through state control of trade, both

countries maintain domestic prices well above border prices. Following South Africa, these two countries have the highest per capita GDP's in the sample. Countries studied where negative protection dominates include India, Nigeria, and Sudan, all at the lower end of the per capita income scale.

Studies of protection in LDC agriculture reveal several results of interest to the United States in the context of its participation in the current agricultural trade negotiations. First, the evidence that countries increase agricultural protection as their national incomes increase suggests that GATT

Country rankings by PSE's, 1982-86

Commodity	Ratio of PSE to commodity value--		
	Positive 1/	Small 2/	Negative 3/
Wheat	Brazil Mexico South Africa South Korea Taiwan		Argentina India Nigeria
Corn	Mexico South Africa South Korea Taiwan	Brazil Nigeria	Argentina
Rice	Brazil Indonesia South Korea Taiwan	Thailand	India Nigeria
Sorghum/ barley	Mexico South Korea Taiwan		Argentina
Soybeans	Mexico South Korea Taiwan	Brazil	Argentina India
Rapeseed		India	
Peanuts	India		
Cotton	Brazil Mexico		India Nigeria Sudan Pakistan
Beef, poultry, & dairy	South Korea Taiwan	Brazil (poultry)	Brazil (beef)
Pork		South Korea Taiwan	
Sugar	Taiwan		Nigeria South Africa
Cocoa			Nigeria

1/ Ratio is plus 0.1 or larger. 2/ Ratio is between minus 0.1 and plus 0.1.  
3/ Ratio is minus 0.1 or smaller.

Source: ERS calculations.



Annual average value of transfers to producers by policy type, 1982-86 1/

Country	Per capita : GDP 2/ (1985)	Overall : PSE	Input : policies	Output : policies	Exchange : rate : policies	Total : transfers
	Dollars	Percent	-----Million dollars-----			
Taiwan	3,097 3/	19	99	841	NM	940
South Korea	2,150	60	1,193	3,690	NM	4,883
Argentina	2,130	-19	0	-1,163	646	-517
Mexico 4/	2,080	41	646	375	369	1,390
South Africa	2,010	29	349	861	160	1,370
Brazil	1,640	4	2,132	-64	-394	1,674
Thailand	800	1	69	-42	NM	26
Nigeria	800	-41	62	17	-804	-725
Indonesia	530	14	594	-366	NM	960
Pakistan	380	20	77	-289	NM	-212
Sudan 5/	300	-11	1	34	-70	-35
India	270	-18	974	-5,190	NM	-4,216

NM = Not measured. 1/ Commodity coverage varies by country. 2/ Source: (16).  
3/ Source: International Monetary Fund. 4/ 1982-85. 5/ 1982-84.

Source: ERS calculations.

negotiations which include LDC's offer an opportunity to halt this trend. Second, the importance of input policies as a means of offsetting LDC producer taxes suggests that a GATT agreement to reduce all subsidies (as opposed to just subsidies through border policies) could pose special adjustment problems for LDC's. This is particularly true where the implementation of such an agreement is not accompanied by policy changes designed to reduce the taxing effects of other agricultural and exchange rate policies. Finally, this GATT round sets the stage for an alliance between the United States and LDC's aimed at restoring an agricultural trade environment in which U.S. agricultural exports could prosper directly, through the reduction of world agricultural protection, and indirectly, through economic growth in LDC's.

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## TRENDS FOR GRAIN CONSUMPTION, PRODUCTION, AND TRADE IN THE DEVELOPING COUNTRIES

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**Abstract:** The developing countries' rapidly accelerating growth in demand for food is exceeding their capacity to expand domestic production. Their increasing dependence on foreign supplies may create growing markets for U.S. exports of food grains and coarse grains.

**Keywords:** Developing countries, grain, production, consumption, trade, dependency.

In the developing countries, food production is generally increasing more rapidly than population but less rapidly than consumption (notable exceptions include some countries in Sub-Saharan Africa, where population is increasing faster than production and consumption). Thus, imports by the developing countries are climbing. These larger imports reflect both rapidly expanding population and economic development. Two important economic forces affecting consumption are rising per capita income and increasing urbanization.

Not only does food consumption increase with rising incomes, but consumption patterns change. With higher incomes, consumers substitute livestock products and other more costly foods for staple foods of coarse grains and roots and tubers. More domestically produced livestock products require, in turn, additional supplies of feedstuffs.

This article reviews the ongoing changes in food grains (wheat and rice) and coarse grains (corn, sorghum, millet, and barley) in the developing countries, and contrasts their situation with the industrial market countries. Developing countries and industrial market countries are defined as in the World Bank's *World Development Report 1985*. China is not included in this discussion.

### *Consumption Nearly Doubles*

Total consumption of both food grains and coarse grains has almost doubled in the developing countries during the past 20 years,

Consumption patterns in the developing and industrial market countries

Item	Food grains		Coarse grains	
	Devel- oping	Indus- trial	Devel- oping	Indus- trial
Percent change 1961-63 to 1980-82				
Consumption				
Food 1/	92	6	44	27
Feed	168	108	199	60
Food and feed	94	19	89	59
Per capita				
Food	22	-10	-9	8
Feed	70	76	90	36
Food and feed	23	1	20	35

1/ Food use includes direct consumption of primary and milled products.

Source: FAO food balance tape.

exceeding population growth and raising per capita consumption. The patterns underlying the higher consumption of these two commodity groups are quite different, though.

In the developing countries, almost all of the food grains are consumed directly. For the coarse grains, a large, but declining, proportion is consumed directly as food. In contrast, little of the coarse grain consumed in the industrial market countries is utilized directly as food. Per capita consumption of coarse grain as food has declined in the developing countries. Use of coarse grains as livestock feed has increased rapidly, however, because of the strong derived demand for feedstuffs created by the larger output of domestic livestock products.

### *Production Outpaces Population*

In the developing countries, the increase in per capita production in the last two



Production changes in developing and industrial market countries

Item	Food grains		Coarse grains	
	Devel- oping	Indus- trial	Devel- oping	Indus- trial
	Percent change 1961-63 to 1980-82			
Production	80	70	65	105
Per capita	14	44	4	74
Area	28	29	15	35
Yield	40	32	44	51
Proportion of total area	5	6	-7	11
	Ratio of yield to area 1/			
	1.4	1.1	3.0	1.5

1/ The yield contribution is the change in yield from 1961-63 to 1980-82 multiplied by 1961-63 harvested area. The area contribution is the change in area from 1961-63 to 1980-82 multiplied by 1961-63 yield.

Source: FAO production tape.

decades has been most significant for the food grains. Nevertheless, it is imports that have allowed consumption of food grains and especially coarse grains to increase more rapidly than production in the developing countries. In contrast, production has grown more rapidly than consumption in the industrial market countries, including the United States.

The larger production of food grains and coarse grains in the developing countries, as well as in the industrial market countries, has resulted from both improved yields and expanded acreage. These two commodity groups together occupy a relatively large proportion of total harvested areas—65 and 68 percent in the developing and industrial market countries, respectively, in 1980-82. The coarse grain harvested area in the developing countries increased less rapidly than the area devoted to food grains and the total harvested area. Thus, the proportion of total harvested area in coarse grains declined.

The percentage improvement in crop yields in the developing countries was about the same as in the industrial market countries. In both groups, the contribution of improved crop yields to increased production was greater than the contribution of expanded harvested area from 1960 to 1982, especially for coarse grains. In the developing countries, the yield contribution of coarse grains was three times larger than the effect of expanded harvested area. Crop yields have been rising with the spread of higher yielding varieties;

greater use of fertilizer, herbicides, and insecticides; expanded use of irrigation in some areas; and other technological innovations.

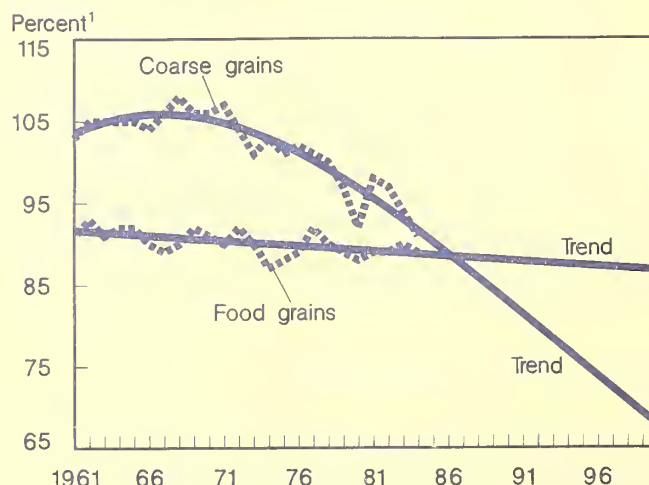
Despite these significant increases in production, though, the developing countries have steadily increased imports from the industrial market countries because of the combination of rapidly growing populations and economic development.

### Trade To Increase

The developing countries' increasing dependence on foreign grain supplies can be seen in the trends for domestic production as a percentage of the sum of domestic production and net imports. Self-sufficiency for coarse grains is trending down more rapidly than for food grains. The developing countries were net exporters of coarse grains during the 1960's and early 1970's, however, their coarse grain imports have increasingly overshadowed exports.

The developing countries' food grain imports have also increased, but their dependence on food grain imports has grown more slowly than that for coarse grains over the past two decades. Projecting these self-sufficiency trends into the future dramatizes the differences between the two commodity groups. Continuation of these trends represents potential growing markets for U.S. exports of food grains and coarse grains. [Gary Vocke (202) 786-1706]

### Self-sufficiency Declines as Grain Use Outpaces Production



1 Production as percent of production plus net imports.

# HIGHER INCOME DEVELOPING COUNTRIES INCREASING COARSE GRAIN IMPORTS

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**Abstract:** During the past two decades, the upper-middle-income developing countries have shifted from being net exporters of coarse grains to net importers. A key factor underlying this trend is that consumers in these higher income developing countries are including more meat and poultry products in their diets. The derived demand for coarse grains created by this increased demand for animal products is increasing faster than production. The resulting shortfall has created large and growing markets for coarse grains.

**Keywords:** Coarse grains, developing countries, livestock feeding.

The shift of developing countries from self-sufficiency in coarse grains to dependency on imports is part of a general decline over the past two decades in the developing world's self-sufficiency in both food and coarse grains (8)\*.

A key factor underlying this trend for coarse grains is a structural diet change resulting from economic development. Consumers in the higher income developing countries are including more meat and poultry products in their diet. To meet increased demand, these countries are developing and expanding their intensive livestock production systems, feeding coarse grains. The derived demand for coarse grains is increasing faster than production. Over the past 2 decades, the upper-middle-income countries have shifted from net exporters of coarse grains to net importers because of this shortfall.

## Role of Developing Countries in World Coarse Grain Economy

Coarse grains are grown on about 45 percent of the world's cereal grains land. Wheat and rice occupy the largest areas, followed by corn, barley, sorghum, and millet. Of these coarse grains, corn is by far the most important, with an average area during 1983-85 of 126 million hectares and an average production of 428 million tons. Barley had an average harvested area of 79 million hectares and production of 172 million tons. Sixty-six million tons of sorghum and 30

million tons of millet were harvested on 47 and 42 million hectares, respectively. One-half of the total area of these four coarse grains is in the developing countries, not including the People's Republic of China.

Although the developing countries have half the world's coarse grain area, they have only one-fourth of the production because average yields are so low—1.2 tons per hectare, compared with 4.8 for the developed countries. The developed countries are almost the reverse, with only one-quarter of the coarse grain area and almost 50 percent of world production.

In the early 1970's, the developing countries produced a larger percentage of the world's coarse grain output than they consumed. Now, use exceeds production by 11 percent. More than 40 percent of consumption is as livestock feed. The percentage utilized as feedstuffs is much smaller than for either the developed or the centrally planned countries, which feed 78 and 68 percent of their coarse grains, respectively.

Coarse grain production, use, and trade in developing countries, 1983-85 average

Item	Corn	Sorghum	Barley	Millet
	Percent			
Production	57	21	10	12
Exported	12	10	3	--
Consumption	56	19	14	11
Used as feed	45	39	67	3
Imported	20	15	37	--
From U.S.	60	76	8	NA

-- = less than 1 percent. NA = not available.

\*Numbers in parentheses refer to literature cited at the end of this article.



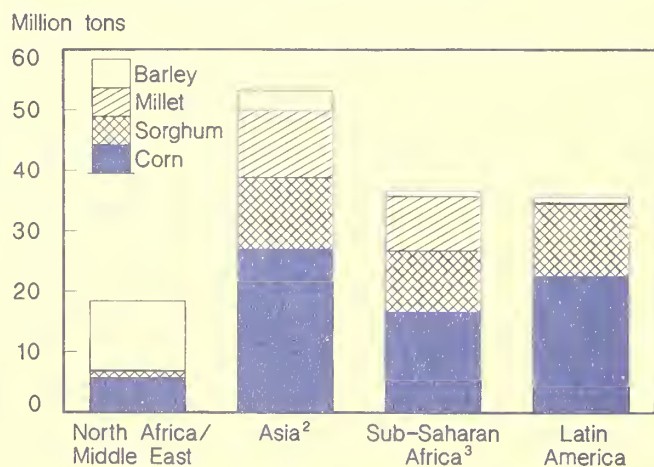
## Coarse Grain Production and Imports

Corn is the most important coarse grain in the developing countries, with over half of total production. In Central America and Sub-Saharan Africa, corn is an important food. In the Middle East and North Africa, where wheat is dominant, and in Asia, where rice is the major crop, corn accounts for a smaller proportion of cereals consumed directly by people.

Sorghum and millet are important food crops in the semi-arid tropics of Asia and Sub-Saharan Africa, where they are particularly well adapted. Sorghum is also grown in South America and Mexico, but primarily for feed use. Corn is an important feedstuff in South America, particularly Argentina and Brazil. Barley is primarily grown as a feedstuff in the more temperate environments of the Middle East and North Africa.

Although 12 percent of the corn and 10 percent of the sorghum grown in the developing countries is exported, only 2 countries are significant exporters: Argentina and Thailand. Argentina has 65 percent of the corn exports and 86 percent of the sorghum exports. Thailand accounts for 28 and 9 percent of the corn and sorghum exports, respectively. Together they account for 93 percent of the corn exports of the developing countries and 95 percent of the sorghum.

### Regional Coarse Grain Production<sup>1</sup>



1/ Annual average, 1983-85. 2/ Excludes Japan and PRC.  
3/ Excludes South Africa.

Twenty percent of the corn consumed in the developing countries is imported. Unlike exports, these imports are widely dispersed. The four largest importers are South Korea, Taiwan, Mexico, and Egypt, who account for almost one-half of all developing-country corn imports. Adding the purchases of the next four largest importers of corn (Brazil, Malaysia, Venezuela, and Iran) accounts for two-thirds of the corn imports of the developing countries. Sorghum imports are more concentrated: Mexico, Venezuela, and Taiwan account for two-thirds of all developing country imports. Mexico by itself has more than 40 percent of these sorghum imports. Saudi Arabia, Iran, Taiwan, and Algeria account for two-thirds of barley imports, with Saudi Arabia taking more than half.

The United States supplies a significant proportion of the corn and sorghum imported by the developing countries. The small amount of barley exported to developing countries is mostly from Europe.

### *Corn, Sorghum, and Millet in Asia and Sub-Saharan Africa*

Corn, sorghum, and millet are the three main nonirrigated cereals in Asia and Sub-Saharan Africa. These crops have physiological differences that make each more or less suited to production in tropical regions. Sorghum and millet are important crops in semi-arid tropical regions because they tolerate periods of moisture and heat stress better than corn. Corn is a higher risk crop in the drier areas, whereas sorghum can usually produce some grain, even under low rainfall. Millet is even better adapted to extremely dry conditions because it matures more rapidly than sorghum, so it can be grown with less rainfall.

The largest corn producers among the developing countries in Sub-Saharan Africa are Zimbabwe, Kenya, Nigeria, and Tanzania. The larger commercial farmers and some smallholders, especially in Kenya and Zimbabwe, growing corn in more temperate environments use hybrids with yields much improved over the local varieties. In the tropical, lowland areas with adequate moisture, farmers grow improved local varieties.



Physiological differences among corn, sorghum, and millet

Item	Corn	Sorghum	Millet
Rooting system	Superficial, in the upper 50 cm	Stronger and deeper than corn	Stronger and deeper than sorghum
Water requirements (mm) over the growth period	500-600	400	300-350
Temperature requirement (°F)	Optimum 77 Minimum 59 Maximum 113	Sorghum and millet have temperature requirements similar to corn, but can withstand higher maximum temperatures.	
Yield (kg./ha.)			
High inputs	4,000-5,000	3,000	1,000-1,500
Low inputs	1,000	750-1,000	500-700

Source: Frere (3)

The corn grown in the semi-arid, tropical areas is unimproved varieties. However, even though corn is not well suited to these semi-arid areas, it may still be grown because it is the preferred foodstuff or is better protected against grain-eating birds. Consumer preference is very important because these grains are grown in Sub-Saharan Africa primarily for human consumption. In Sub-Saharan Africa, Nigeria is the major sorghum producer, followed by Sudan and Ethiopia. The major millet producers are Nigeria and Niger.

In Asia, India is the major producer of corn, sorghum, and millet, primarily for human consumption. India grows more than 10 million tons each of sorghum and millet and 8 million tons of corn. It is the world's largest producer of millet and the second largest producer of sorghum after the United States. Corn is the fourth most important crop in Thailand. Sorghum is a minor crop grown in the dry season following corn. In 1983-85, Thailand produced about 4.5 million tons of corn and 0.4 million tons of sorghum, and exported an average of 3.1 and 0.3 million tons, respectively.

*Barley in North Africa and Middle East*

Barley, a more temperate-climate crop than corn, sorghum, and millet, is important in the Middle East and North Africa. It is a short-season crop that is more dependable than wheat in dry regions. Barley is important to the sheep economy of the Middle East and

North Africa. Often it is grazed at the tillering stage and then allowed to grow to maturity for both its grain and straw.

*Coarse Grains in Latin America*

Corn and sorghum are important crops in South America. Argentina and Brazil are the major producers, and Argentina is the largest exporter of coarse grains in the developing world. Domestic use of these crops is primarily for feed. In 1983-85, Argentina produced about 11.2 million tons of corn and 5.9 million tons of sorghum, and exported an average of 7.3 and 3.1 million tons, respectively.

Corn is widely grown in Central America as a foodgrain. Sorghum, however, supplies the expanding feed and livestock industry of Mexico. Since farmers in Mexico started growing high-yielding sorghum hybrids from the United States, average yields have increased much more rapidly than for corn, making sorghum the lowest-cost feedstuff.

**Coarse Grain Use**

*Related to Per Capita Income*

Per capita income is a principal determinant of coarse grain use patterns. Once a country achieves an income level at which average basic cereal calorie requirements are fulfilled and income is available to buy meat, the feed use of coarse

grains can increase rapidly. Thus, empirical studies have shown a strong, positive relationship between per capita income and the use of cereals as feed (5, 6). In contrast, studies at the International Maize and Wheat Improvement Center (CIMMYT) have found no significant relationship between per capita income and use of corn directly as food. Per capita food use has been relatively constant across all developing countries the past two decades.

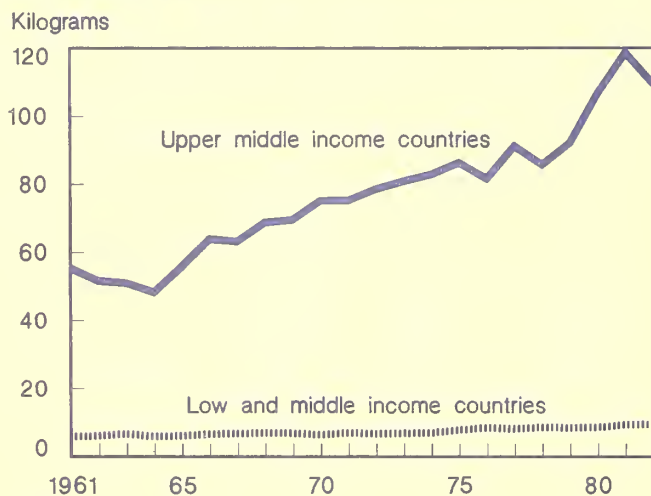
### Feed Use of Coarse Grains

The increased use of coarse grains as feed implies considerable potential for expansion of the use of these crops. For example, 1 kilogram of livestock production from an intensive production system requires from 2 to 6 kilograms of grains. Because of this leverage, as livestock products increase in the diet, use of grains as feedstuffs can grow very rapidly, more rapidly than income.

Per capita use of coarse grains as feed, relatively high and rising in the upper-middle-income developing countries, has shifted these countries as a group from net exporters to net importers. Feed use in the lower income countries is low and constant.

Corn is the most important feed source in the developing countries, as in the world at large. Wheat bran and rice bran are the second most important. Sorghum, barley, and

### Per Capita Feed Use of Coarse Grains in the LDC's



Source: FAO

### Feed substitution of corn for swine and poultry

Feed	Feed value relative to corn 1/	Extent feedstuff can replace corn
		Percent
<b>Swine</b>		
Corn	100	100
Barley	90-95	100
Millet	85-90	50
Sorghum	95	100
Wheat	100-105	100
Wheat bran	75	15-25
Rice	80-85	50
Rice bran	100	33
<b>Poultry</b>		
Corn	100	100
Barley	80-85	50
Millet	95-100	65
Sorghum	100	100
Wheat	90-95	100
Wheat bran	75	10-15
Rice	80-85	20-50
Rice bran	50	5-10

1/ Pound for pound.

Source: Ensminger (2)

millet make up most of the balance of total feed supplies. As a share of developing-country feed supplies, corn is 43 percent; wheat and wheat bran, 18; rice and rice bran, 18; sorghum, 9; barley, 7; millet, 2; and others, 3 (1). The contributions of wheat and rice are largely bran. The four coarse grains discussed here are 61 percent of total feed supplies.

Corn is one of the best feeds for livestock because it is high in digestible nutrients and net energy. However, other cereals can substitute for corn in livestock rations, within limits. Their use will vary from country to country, reflecting supplies, government policies, and relative prices.

For example, where wheat consumption is rising, the use of wheat bran for feed is also rising. In some countries which have become major wheat importers, the use of wheat bran as feed is increasing more rapidly than the use of corn. Heavily subsidized wheat prices can also lead to the use of wheat for animal feed. Major rice producers depend significantly on broken rice and rice bran as feed sources. For example, 23 percent of feed used in Thailand's rapidly growing livestock sector is rice, 36 percent is rice bran, and 30 percent is corn (7). Countries with relatively large barley or sorghum crops rely more on these grains.



## Coarse grain imports, upper middle income LDC's

Country	Corn	Sorghum	Barley
Percent 1/			
Asia			
South Korea	15	6	--
Taiwan	15	10	4
Malaysia	5	--	--
Hong Kong	2	--	--
Singapore	2	--	1
Latin America			
Mexico	11	43	--
Venezuela	4	13	--
Brazil	7	--	2
Panama	--	--	--
Trinidad	--	--	--
Uruguay	--	--	--
Argentina	--	--	--
Chile	--	--	--
North Africa Middle East			
Saudi Arabia	3	--	54
Algeria	2	5	4
Iran	3	--	6
Jordan	--	--	2
Syria	1	--	2
Oman	--	--	--
Libya	1	--	3
Kuwait	--	--	2
Israel	1	10	3
Iraq	2	--	4

1/ Percent of developing countries' imports of commodity in 1983-85. -- = less than 1 percent.

It is estimated that over two-thirds of the grains used for feed in the developing countries are fed to poultry and swine (1). Growth rates for broiler production have been particularly strong in the Middle East, Southeast Asia, and Western and North Africa. In each of these regions, the rapid growth has resulted from the introduction of more feed-efficient birds, and investment in intensive poultry production units and associated feed manufacturing units. Egg production has also expanded rapidly in the developing world, although not as dramatically as poultry meat. The growth in eggs has also been associated with implementation of intensive production methods.

The growth in pork production in developing countries, although less rapid than poultry meat and egg production, has also boosted demand for coarse grains significantly. This is because pork production uses more grain per unit of output than poultry. Under good conditions in an intensive production system, 5 to 6 kilograms of feed are required to produce 1 kilogram of pork, whereas only 2 to 3 kilograms are required to produce 1 kilogram of poultry meat. The

strongest growth in pork production is in Central America and East Asia. Dairy and beef production has contributed little to the demand for feed grains.

*Rising in Upper-Middle-Income Countries*

The use of coarse grains in the upper-middle-income countries has increased much faster than production, and was the driving force in shifting the developing world from being net exporters to net importers of coarse grains in the late 1970's. This group includes all the major coarse grain importers discussed earlier except Egypt. (Note that this group also includes Argentina, a major coarse grain exporter.) Generally, coarse grain imports by these countries appear unlikely to be offset by rapid increases in domestic production, as happened with the green revolution in wheat for India and Pakistan.

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# THE IMPACT OF ECONOMIC DEVELOPMENT ON GLOBAL FOOD DEMAND PATTERNS

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**Abstract:** This article analyzes global food demand for coarse grains, wheat and rice, and meat. The mix of these commodities demanded at various income levels appears to change in a predictable manner as economic development proceeds. This analysis anticipates the direction and the magnitude of these changes in demand.

**Keywords:** Food demand, economic development, income, consumption patterns.

The study of global wheat and rice demand is important to the future of U.S. trade, since the United States is the largest wheat exporter and the second largest rice exporter in the world. Understanding the demand for meat provides insight into future demand for feed grains, of which the United States is a leading exporter.

## *The Data*

The analysis uses food consumption quantities derived from the food balance data tapes of the Food and Agriculture Organization (FAO) of the United Nations for the period 1966-80 for 105 countries. To permit direct comparison among, and aggregation of, the food groups in the study, the edible primary and secondary products were converted to calories and expressed as a percentage of total calories consumed per capita per day. This measure is referred to as "percentage of total diet." 1/

Estimates of per capita gross domestic product adjusted for purchasing power parity in constant 1975 international dollars are used to measure economic development. 2/ The

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1/ For full details of the study, see Suzanne Marie Marks and Mervin J. Yetley, *Global Food Demand Patterns Over Changing Levels of Economic Development*, ERS Staff Report No. AGES870910, October 1987.

2/ Further mention of per capita income will refer to constant 1975 international dollars.

study refers to this variable as "per capita income."

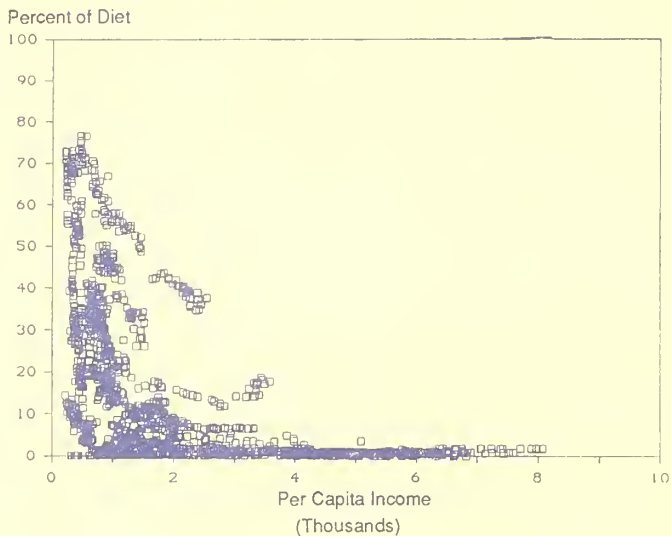
## *The Analysis*

It is often assumed in economic literature that demand for food is a simple declining linear function of income. In this study, it is hypothesized that as income increases, a food group will change in consumers' preference from a preferred item to a necessity, and finally to a less preferred item. If this hypothesis is correct, food demand is not a constant declining linear function, but a more complicated function that changes in a nonlinear manner as income increases. Further, the nature of the function is not expected to be identical for the three food groups in the study.

With economic development, demand for the least preferred foods is expected to fall in a nonlinear manner. Graphic analysis of coarse grain data suggests that this food group is an economically inferior commodity group at all levels of income (figure 1). Apparently, coarse grains are never considered a luxury item, or even a necessity, as incomes increase.

Wheat and rice data show two distinct patterns (figures 2 through 4). A group of 80 countries clearly forms a pattern that follows the hypothesis stated above. The 25 countries in the second group consume a much larger proportion of their diet as wheat/rice than countries in the first group. Many of these countries subsidize production or consumption of either wheat or rice, causing consumption

**Figure 1--Coarse Grain Consumption 1/  
(Scatter Graph of 105 Countries)**



1/ The apparent zero values are a scale problem on the plot, not actual zero levels of consumption1

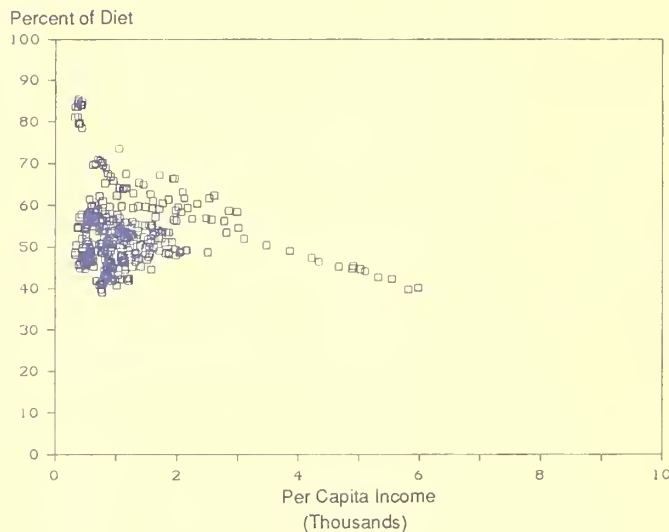
**Figure 2--Wheat and Rice Consumption  
(Scatter Graph of 105 Countries)**



**Figure 3--Wheat and Rice Consumption  
(Scatter Graph of 80 Countries)**



**Figure 4--Wheat and Rice Consumption  
(Scatter Graph of 25 Countries)**



to be artificially higher than it normally would be.

For the 80 countries, it appears that wheat/rice is considered a preferred good at low income levels, then becomes a necessary good as coarse grain consumption is reduced. Finally, wheat/rice becomes an inferior good as income levels permit meat to be substituted into the diet.

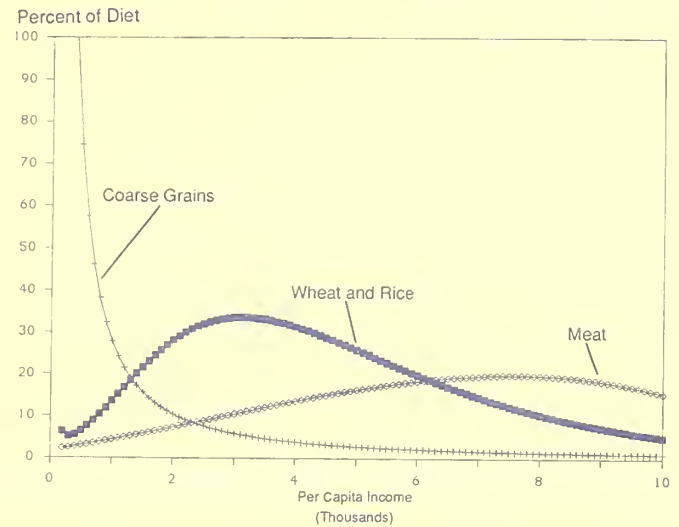
Meat consumption is assumed to follow a pattern similar to wheat and rice (figure 5). Thus, meat may be considered a preferred good in the low-income range, where increasing demand would be expected. Then, at some income level the rate of increase in consumption decreases. Possible decreases in absolute meat consumption are foreseeable as the variety of foods in the diet increases.



**Figure 5--Meat Consumption  
(Scatter Graph of 105 Countries)**



**Figure 6--Food Consumption/Percentage of Diet for  
Wheat and Rice, Meat, and Coarse Grains**



The estimated functions and statistical results of the equations for each of the three food groups show that as income increases: the percentage of coarse grains in the diet decreases; the percentage of wheat/rice in the diet increases, then decreases; and the percentage of meat in the diet increases until very high income levels are reached, then decreases.

### *Implications*

The findings show significant variations in the percentages of coarse grains, wheat/rice, and meat in the diet with changing per capita income. The estimated food demand functions enable anticipation of the direction and magnitude of variations in the diet over the observed income range.

When these variations are plotted together over the income range, as in figure 6, we can make some general observations about the tendency of these food groups to substitute for or complement each other. At low income levels, coarse grains account for a large proportion of the diet. But as incomes rise, the percentage of coarse grains in the diet decreases rapidly and is overtaken by wheat and rice. As incomes reach higher levels, the proportion of meat in the diet exceeds that of wheat and rice.

Thus, without calculating cross-price elasticities of demand (the percentage change in demand for a food in response to changes in

its own price and in those of substitute or complementary foods), and allowing for differences in food preferences among countries, it appears that wheat and rice generally substitute for coarse grains at lower income levels. Then, at higher incomes, meat substitutes for wheat and rice in the diet. From approximately \$300 to \$3,100, consumption of meat products and wheat and rice complement each other.

Income ranges can be identified with particular food patterns. Developing countries in the lower income ranges modify their food commodity mix as incomes increase by replacing traditional foods in the diet, such as coarse grains, with wheat and rice. Thus, demand pattern adjustments occur among the staple commodity groups. For countries in the lowest income range, meat is not in the effective field of choice. In these countries, consumers are still too poor to effectively demand more than the cheapest of food commodities. But, as per capita incomes rise past \$300, meat enters the effective field of choice and complements wheat and rice.

As countries pass through the middle ranges of income, wheat and rice consumption peaks and then decreases. Substitution of meat for grains takes place. The rise in meat demand continues until high levels of income are attained. Meat consumption as a percentage of the diet surpasses wheat and rice consumption at approximately \$6,200 in the high-income range representing developed

market economies. However, the share of meat in the diet tends to reach a saturation point, and even declines at extremely high income levels.

Although this study does not focus on the projection of food demand patterns for a specific country, it seems reasonable to expect individual countries to follow the global patterns exhibited in figure 6. Unless special climatic or cultural factors cause departure from these patterns, we may expect most deviations to be transitory in nature.

As incomes increase and dietary demands change, the potential for trade increases since it is often cheaper to import than to produce domestically. Trade potential will be driven by demand in the middle- and upper-income developing countries, especially by the derived demand for feed. Import growth will likely occur in the upper-income developing countries due to their greater purchasing capacity. U.S. agriculture, as the leading exporter of both food and feed grains, could benefit from increased volume of trade with these countries.

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## THE GREEN REVOLUTION LAGS RISING WHEAT CONSUMPTION IN THE DEVELOPING WORLD

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**Abstract:** Wheat imports by developing countries have doubled since the early 1960's even though wheat output in the developing world rose more than 150 percent. Most countries of the developing world have become more dependent on wheat imports to meet rising demands. The Green Revolution has allowed some wheat importing countries to achieve self-sufficiency.

**Keywords:** Green Revolution, wheat, developing countries, agricultural policy, high-yielding varieties.

Wheat consumption is increasing throughout the developing world with rising incomes and urbanization. Per capita consumption of wheat is growing faster than per capita production, reflecting an increasing dependency on rising wheat imports. The Green Revolution, however, has increased wheat output greatly in the traditional, spring-wheat growing countries, reducing and in some cases eliminating imports. Because wheat is not well suited for tropical climates, the Green Revolution has not significantly increased wheat output in these areas.

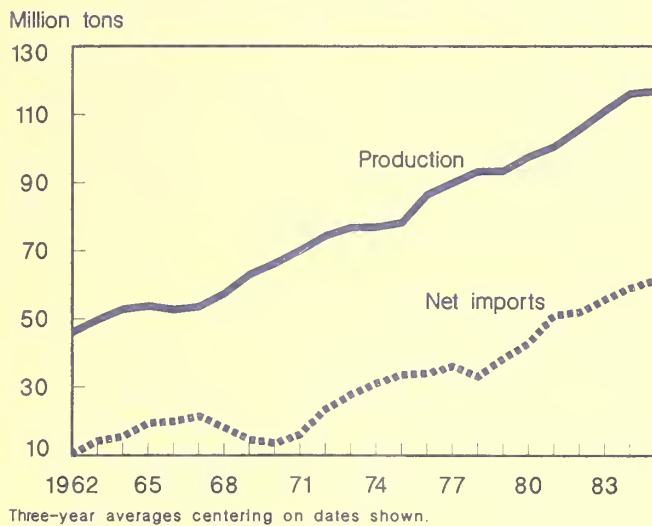
Demand for wheat products, however, continues to increase in the tropics. To a large extent, the rising demand in the tropics has been met with imports. This is why wheat imports by the developing countries have grown 100 percent since the early 1960's even though wheat output in the developing world rose more than 150 percent.

*Wheat Consumption Increases in LDC's*

Rising incomes and increasing urbanization explain much of the increasing



## LDC Wheat Production and Net Imports Rise



per capita wheat consumption in developing countries (LDC's) (4). 1/ Consumption is usually higher in urban areas than in rural areas so the migration to the cities is increasing the demand for wheat. Wheat consumption in developing countries also tends to rise with incomes, usually at a faster rate than for other staples. The direct association between increasing wheat consumption and rising incomes also reflects considerable substitution of wheat for other starchy staples. Furthermore, as economic development and urbanization proceed, sales of wheat flour decline and sales of processed products, such as bread, increase. Among the lower-income, wheat-consuming countries, over 90 percent of the milled wheat is bought as flour for home baking and cooking (5). As per capita income increases, wheat products baked outside the home replace flour as urban people are more willing to pay extra for foods requiring little preparation. Rapidly increasing wheat consumption has led to greatly increased wheat imports in developing countries where wheat is not a suitable crop.

Where rising demand for wheat has exceeded domestic output, many countries have turned to imports. Imports for urban consumers help overcome domestic problems such as bottlenecks in domestic transportation, limited rural storage, year-to-year fluctuations in supplies, and

1/ Numbers in parentheses refer to sources listed at the end of the article.

problems of quality control, especially with other grains such as sorghum. In Sub-Saharan Africa, for example, population in the major capitals is growing at an average annual rate of 9 percent (5). If these cities were to depend on domestic supplies, internal transportation and storage capacity would have to double every 8 years simply to maintain per capita consumption. Thus, many developing countries find it easier to import wheat than to supply their cities with food from rural areas. Consequently, Sub-Saharan Africa has one of the highest growth rates of imported wheat consumption.

Food aid, usually wheat, has helped increase consumer preferences for wheat products. In addition, food products from imported wheat are often less expensive than products from other grains because of government policies.

A few countries have met their rising demand for wheat with dramatic increases in domestic output, the Green Revolution for wheat. In other countries, particularly the tropics where little wheat is grown, increased consumption has been supplied by ever larger imports.

### *Wheat Green Revolution Starts In Mexico*

The Green Revolution for wheat refers to the dramatic gains in crop productivity that came from replacing traditional wheat varieties with semi-dwarf varieties, increasing the use of inputs, and improving management. The research that created semi-dwarf varieties began as a cooperative venture between Mexico and the Rockefeller Foundation at what is now called CIMMYT (International Maize and Wheat Improvement Center). Researchers developed short-stemmed, high-yielding wheat varieties in the 1950's by crossing rust-resistant Mexican varieties with American semi-dwarf varieties (developed in the 1940's at Washington State University using varieties from Japan). By the 1960's, the Mexican and American varieties had been successfully crossed and the seed distributed to farmers, greatly increasing Mexican wheat yields through the 1970's.

The semi-dwarf varieties proved well adapted to the wheat-growing regions of many

developing countries. India and Pakistan began importing seed for commercial planting from Mexico in 1965; Turkey, in 1967. When grown using recommended practices, including irrigation and fertilization, the semi-dwarf varieties increased yields two and three times those of native varieties. The rapid expansion of the area planted to semi-dwarf varieties during the 1960's started the Green Revolution and has steadily increased production in the wheat-producing countries of the developing world.

The semi-dwarf varieties used more fertilizer, water, and pesticides to substitute for land expansion as the primary basis for increased output. Before the Green Revolution, production increases were due more to expanded areas than to higher yields. By the end of the 1960's, yields were improving rapidly and were making the larger contribution. By the 1980's, most of the increase in output was due to yield increases (12).

The major wheat-growing areas of the developing world have nearly completed the switch to semi-dwarf varieties (6). Mexico, India, Pakistan, Turkey, and Argentina now have 84 percent of the total area planted to semi-dwarf varieties in the non-Communist, developing world (7). The spread of these varieties was typically associated with important policy changes. Farm prices were raised, fertilizer manufacture and distribution stepped up, and seed production improved. Other important changes occurred too. For example, in India the profitability of the high yielding semi-dwarf varieties financed wells to shift lands from rain-fed crops, such as coarse grains, oilseeds, and pulses, into irrigated wheat production. As increasing production eliminated the need for imports,

some countries, such as Mexico in the late 1960's, sometimes reduced their incentives to wheat farmers to avoid subsidized surpluses, which would have to be exported in competition with the traditional wheat exporters (12). Except for Argentina, these major wheat-producing developing countries generally are concerned with national self-sufficiency and thus are not expected to become significant exporters (12).

The key elements of the Green Revolutions in Mexico, India, and Pakistan were semi-dwarf varieties, irrigation, and increased fertilizer use. Mexico briefly became a net exporter during the 1960's, but began importing again on a large scale after 1970 because consumption was increasing faster than production. Today, Mexico is self-sufficient in food wheat and imports only feed quality wheat. Increased wheat output in India and Pakistan allowed imports to trend downward in sharp contrast with the general trend for developing countries. These two countries, which were once the major importers in the developing world, now fluctuate around self-sufficiency.

Turkey's Green Revolution in wheat was initially limited to the irrigated, spring wheat regions on the coast because the Mexican semi-dwarf varieties were spring wheats. The Green Revolution was later extended to the dryland, winter wheat regions with the development of improved management practices and suitable varieties from Russia and the United States. The increased output allowed Turkey to become a wheat exporter for several years. Recently, however, production slowed and the country is fluctuating between self-sufficiency and being a net importer.

Argentina's wheat yields did not rise as rapidly as elsewhere because the government's industrial development strategy kept wheat prices low and fertilizer prices high, thus discouraging fertilizer use. Argentina nevertheless increased wheat yields and output by adopting semi-dwarf varieties and improved tillage practices.

#### *Wheat Production Constrained In Tropics*

Wheat production on a large scale in tropical countries is presently limited by the

Estimated area planted to HYV wheat, 1982/83

Country	HYV area Mil. ha	HYV share of	
		Country's wheat area Percent	LDC HYV area
India	18.1	79	43
Argentina	6.5	92	16
Pakistan	6.4	88	15
Turkey	3.3	36	8
Mexico	.8	80	2
Total	35.1	74	84

Source: (7).



adverse effects of high temperatures and sometimes unfavorable rainfall and soils. Tropics here are defined as the area between 23 degrees N and 23 degrees S latitude and include Sub-Saharan Africa, Southeast Asia, Central America and the Caribbean (less Mexico), Brazil, and the Andean area. This group of countries has a population of about 1 billion, roughly equally divided among Africa, Asia, and Latin America (2).

Below 1,000 meters elevation in the tropics, very little commercial wheat production occurs, except in the Sudan. (Most of Brazil's wheat is now grown south of 23 degrees S latitude, but future expansion will likely be only in the more tropical zones (2).) The tropics range from humid climates, where wheat can sometimes be grown in the cooler dry season, to the arid regions in Sub-Saharan Africa. Despite the difficulties of growing wheat in these environments, many countries have research and development projects for wheat because of their rapidly growing total wheat consumption—4.2 percent annually in tropical Africa and Asia and 1.6 in tropical Latin America since the early 1960's. These countries import about one-third of all wheat imported by developing countries. Imports provide more than 80 percent of their wheat consumption (2).

#### *Rice Paddies Can Be Used for Wheat*

Millions of hectares of rice paddy land in Asia lie idle during the cooler dry season. Wheat research for this idle land focuses on breeding suitable varieties, developing multiple cropping patterns, and exploring soil management practices, including the effects on wheat of the hardpans that result from puddling the soil for rice (3, 9). Bangladesh is an example where wheat production is being successfully introduced. Wheat area rose from an average 60,000 hectares in 1961–65 to 575,800 in 1981–85.

#### *Hot, Arid Climates Require Irrigation*

Sudan and Nigeria are examples where wheat production is being developed to reduce imports, even though high temperatures hold down yields (1, 11). Wheat production in these countries is being developed on large-scale public irrigation projects requiring large capital investments. Because of the low yields, even under irrigation, production costs

are generally too high for wheat to be economical, especially with the current low international prices for wheat.

#### *Acid Soils Limit Yields*

Some tropical regions have acid soils. Acid soils reduce the availability of phosphorus and contain free aluminum, which inhibits root growth (8, 10). Brazil is an example where research is underway to develop wheat varieties and cropping practices suitable for acid soils. However, there has been little progress in developing varieties for commercial production (4). Brazil has 50 million hectares of acid soils of which 12 million might be suitable for wheat. Similar soils are found in Africa (Zaire, Zimbabwe, Kenya, Tanzania, Zambia, and Mozambique) and in Southeast Asia (Burma, Thailand, Malaysia, and Indonesia).

#### *Summary*

Rising yields now make a larger contribution to increased wheat output than expanding area in the major wheat growing regions of the developing world. Wheat yields can continue to increase as management practices improve and higher yielding varieties are developed. Thus, in those countries where wheat is a suitable crop, it appears that production can grow at least as rapidly as demand. Except for Argentina, however, the major wheat-growing countries of the developing world do not appear likely to become steady, growing wheat exporters. Exportable surpluses in these countries will occur from time to time depending upon the weather.

Expanding wheat production significantly in the tropics requires heat-tolerant varieties. Until these are developed, it is unlikely that yields will be high enough to profitably produce wheat on a large scale. It is cheaper to rely on imported wheat. Thus, countries in the tropics are likely to be growing markets as long as their incomes rise and urbanization continues.

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## CORN PRODUCTION LAGS BEHIND USE IN DEVELOPING COUNTRIES

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**Abstract:** Although corn production in developing countries is increasing with more widespread planting of higher-yielding varieties, output lags behind use and imports are rising. Generally, corn imports appear unlikely to be offset by increases in domestic production due to improved varieties as with the Green Revolution for wheat. Recently, however, demand for corn in some countries has been stymied because incomes are not growing as in the 1960's and 1970's, and because severe indebtedness is affecting ability to import.

**Keywords:** Corn, developing countries, production, consumption, trade, technology, hybrids.

Twenty percent of corn used in developing countries during 1983-85 was imported. The four largest importers were South Korea, Taiwan, Mexico, and Egypt, which accounted for almost one-half of all developing country corn imports. Adding the purchases of the next four largest importers of corn (Brazil, Malaysia, Venezuela, and Iran) accounts for two-thirds of the corn imports of the

developing countries. Over 80 percent of corn imports by developing countries are estimated to be used for livestock, dairy, and poultry feed (1). 1/

The use of corn as feed in the higher-income developing countries has

1/ Numbers in parentheses refer to references at end of article.

increased much faster than production, and was the driving force in shifting the developing world from being net exporters to net importers of corn in the late 1970's and through the 1980's. 2/

Recently, however, use of corn in some countries of this high-income group has been stymied because incomes are not growing as rapidly as in the 1960's and 1970's, and because severe indebtedness is restricting their ability to import. Heavy debt burdens have led some countries to try to achieve self-sufficiency, even with the relatively low prices for corn in the international markets. Examples include Brazil and Venezuela.

### *Corn Yields Are Low In Developing Countries*

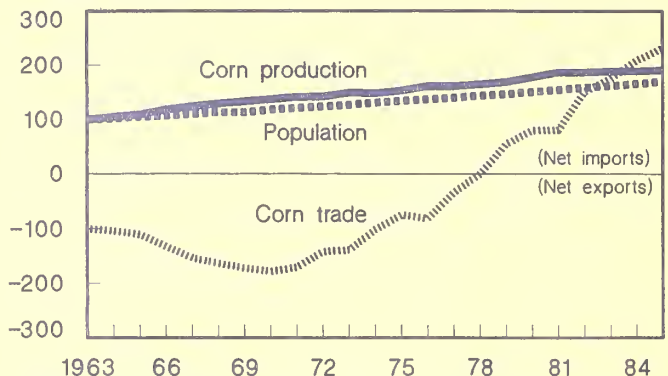
Corn yields are generally lower in developing countries than in developed countries because of the combination of severe disease and insect problems, little fertilizer, and use of unimproved varieties. Perhaps as much as 60 percent of the fertilizer used in developing countries is applied on irrigated areas, which are commonly planted to wheat and rice (6). Without assured moisture, typical subsistence farmers are reluctant to use higher levels of inputs, including fertilizer. Under favorable conditions and good management, however, yields can be quite high. For example, the large-scale commercial farmers in Zimbabwe have averaged as high as 6 tons per hectare in years of good weather. The national 1984-86 average for Zimbabwe was only 1.8 because more than 80 percent of the corn area is cropped by poorer, largely subsistence farmers using few inputs on marginal land. (The United States averaged 7.2 tons per hectare in 1984-86.)

There are also important physiological differences between tropical and temperate corn varieties, especially in the dry matter going to grain production after flowering (5).

2/ Higher-income developing countries as used here, based on World Bank classifications, comprise the following: Algeria, Argentina, Brazil, Chile, Hong Kong, Iran, Iraq, Israel, Jordan, Kuwait, Libya, Malaysia, Mexico, Panama, Saudi Arabia, Singapore, South Africa, South Korea, Syria, Taiwan, Trinidad, Uruguay, and Venezuela.

### **Higher Corn Imports Make Developing Countries Net Importers**

Percent of 1962-64



3-year averages.  
Index of corn production and population: 1962-64 average=100.  
Index of corn trade: 1962-64 average=-100 (indicating net exports).

The temperate corn varieties have an almost constant stalk and leaf weight after flowering because all the dry matter accumulation is in grain production. By harvest, half of the weight of temperate corn will be in the grain. Tropical corn is not as efficient, about 80 percent of the dry matter goes to grain after flowering and only 30 to 40 percent of weight of the plant will be in the grain at maturity.

Because of low yields, developing countries account for only a quarter of world production, in spite of having half of the world's corn land. Not only are yields much lower in developing countries, they are not increasing as fast as elsewhere. Yield increases contributed less to the increased corn production in the developing countries than in the centrally planned or developed countries during the past decade.

### *Improved Varieties Can Increase Yields*

The benefits of improved varieties are shown by the U.S. experience. Field trials using hybrid and nonhybrid varieties from the 1920's to the 1980's indicate that 60 to 80 percent of U.S. yield gains have been due to improved varieties (7).

About half of the corn area in developing countries is planted to improved varieties, and only one-third to hybrids (3). The improved varieties grown in the developing countries were developed through breeding programs specific to their agro-environment. Although corn can be grown under a wide range of



## Corn yields and production

Region	Average yield		Average production		Share of production
	1973-75	1983-85	1973-75	1983-85	increase due to increased yields 1/
	Tons per ha.		Million tons		Percent
Developing countries:	1.4	1.6	80	100	70
Centrally planned 2/:	2.6	3.9	70	116	75
Developed countries :	5.1	6.4	160	208	79
United States :	5.2	6.4	137	175	81

1/ Change due to yield is change in yield multiplied by harvested area in 1973-75. 2/ Includes People's Republic of China.

Source: (12).

environments, it is generally not possible to transfer varieties from one agro-environment to another. Individual varieties have only narrow adaptability because of their sensitivity to temperature and day length, and their susceptibility to diseases and insects.

A key international corn breeding center for developing improved varieties for the developing countries is the International Maize and Wheat Improvement Center (CIMMYT) in Mexico. Much of the corn breeding at CIMMYT has focused on development of gene pools.

Gene pools are populations of much improved individuals. The plants in a given gene pool are similar for characteristics such as length of growing season and climatic adaptation, that is, tropical highlands, tropical lowlands, or subtropics. The plants in a particular gene pool are grown and cross-pollinated naturally for several generations, with only the seed of the best plants saved at each harvest. The frequency of desirable genes in the gene pool population gradually increases, although a given gene is not likely to be present in every plant. Gene pools can be used to develop open-pollinated varieties and inbred lines for hybrids.

### *Hybrid Varieties Difficult to Develop*

Hybrids are much less common in developing countries because of a lack of organizations for developing hybrid varieties and producing and distributing seed. Open-pollinated varieties are easier and require less time to bring to the marketplace.

Also, the seed of open-pollinated corn can be saved by farmers from each season's crop for planting in the following season. Hybrid seed must be bought new each season.

Hybrid variety development begins with 3,000 to 5,000 viable crosses of inbred lines for each successful variety to be released to farmers (7). Selection, testing, and evaluation lasts for 8 to 10 years. The inbred lines are low-yielding and quite susceptible to adverse growing conditions. Single-cross hybrid varieties result from mating two inbred lines.

Double-cross varieties are developed from mating two single crosses. An advantage of double crosses is the greater yield of the mating because it is a single cross already, not an inbred. Thus, less land and labor are needed to grow double-cross hybrid seed.

The potential benefits of using hybrids is shown in the United States, where single-cross hybrids outyield other hybrids by 5 percent and open-pollinated varieties by 15 percent (7). About 90 percent of U.S. corn acreage is planted to single crosses.

### *Other Corn Breeding Goals*

Efforts are being made to increase disease and insect resistance and to improve protein quality (12). Three corn diseases receiving particular attention are stunt in Latin America, streak virus in Africa, and downy mildew, mainly in Asia.

Corn breeders are also attempting to change protein quality. Because normal corn is low in two essential amino acids, lysine and

Nitrogen fertilizer use for corn production and  
corn yields in selected countries

Country	Percent of area fertilized 1/	Nitrogen application rates 1/	Yield 2/
	Percent	Kg/ha	Tons/ha
Morocco	43	4	0.7
Nigeria	20	9	0.9
Somalia	20	2	1.1
Paraguay	2	1	1.1
Tanzania	12	4	1.2
Pakistan	73	49	1.3
India	50	10	1.3
Colombia	15	8	1.4
Mexico	41	43	1.6
Dominican Republic	15	7	1.7
Turkey	79	55	2.7
Germany	100	180	5.9
France	99	118	6.3
United States	100	140	6.4 3/

1/ Source: (6). 2/ Average 1983-85. Source: (12). 3/ 1983 was a drought year in the United States. The 1984-86 average yield was 7.2 tons per hectare.

tryptophan, a corn based diet lacking in protein foods (usually due to low incomes) can lead to protein deficiency disorders, including kwashiorkor. Kwashiorkor causes high infant mortality in many parts of the world. Lysine and tryptophan are two of the 10 amino acids called essential because humans (and non-ruminant livestock) cannot synthesize them. They must be obtained directly from food consumed. The protein in normal corn is only about 2 percent lysine and 0.5 percent tryptophan; for growth and maintenance of body tissue these proportions should be approximately doubled.

In the 1960's, researchers found mutants with protein that had a lysine content of about 3.4 percent and 1 percent tryptophan. Corn breeders are working to incorporate genes for increased lysine and tryptophan into new varieties.

#### *Corn Used Directly as Food*

Direct consumption of corn provides 8 percent of calories in the diet of developing countries, compared with 17 percent for wheat and 25 percent for rice (2). However, in many African and Latin American countries, corn is the major staple food. Corn furnishes about 40 percent of the total calories consumed in Africa, where about 95 percent of the crop is consumed directly. White flint corn is used

for gruel and a type of couscous. The soft, floury dents are primarily used for soups and porridges.

In Latin America the situation varies. In Venezuela, white flint corn is consumed as a muffin. Tortillas, the thin unleavened cakes which are a staple of Mexico and other Central American countries, can be made from both dent and flint corns. In Brazil, corn is an important foodstuff in subsistence farming areas. Corn is also an important feedgrain in Brazil and Argentina.

Corn is also widely grown in Asia and is important for some lower-income people. Generally, however, little of the calories in the average Asian diet are supplied by corn.

Consumers have strong preferences about the color of corn used in their traditional corn food products. White and yellow corn are only partially substitutable even though the principal difference is the carotin oil in the yellow corn.

Roughly 90 percent of the world's white corn is grown in the developing countries, where it is almost one-third of their corn production (4). For the world as a whole, however, white corn is 7 percent of world production and less than 5 percent of trade.



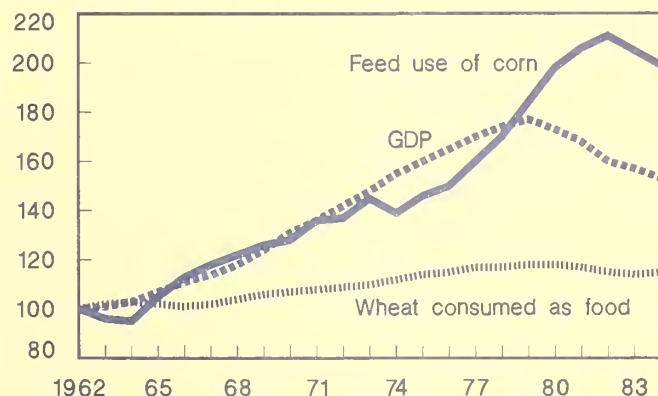
Use of improved varieties and hybrids  
in selected developing countries, 1985-86

Country	Area planted to improved corn as percent of total corn area	Area planted to hybrids as percent of total corn area
	Percent	
Argentina	100	100
Syria	100	88
South Africa	97	95
Taiwan	96	92
Chile	81	68
Zimbabwe	77	60
Thailand	70	8
Brazil	70	63
Kenya	66	61
Zambia	64	53
Egypt	64	10
Peru	50	43
Turkey	46	33
Venezuela	43	30
Nigeria	40	2
India	36	13
Uganda	36	1
Burma	34	0
Togo	33	3
Ecuador	32	3
Cameroon	30	0
Ghana	30	0
Senegal	30	0
Pakistan	28	2
Malawi	26	9
Philippines	26	1
Indonesia	25	1
Colombia	15	13
Tanzania	12	5
Ivory Coast	10	0
Madagascar	4	0
Developed market economies	99	99

Source: (3).

**Feeding of Corn to Livestock Follows Incomes  
In Higher-Income Developing Countries**

Percent of 1961-63



Per capita, 3-year averages.  
GDP is deflated.

*Technology Creating New Foods  
for Urban Consumers*

Meal made from grinding corn in the traditional African way cannot be stored very long because its high oil content causes it to become rancid. With more modern processing practices the germ is removed before grinding. The oil content of the meal then falls from 4 percent to 1.5 percent, improving storage and consumer acceptability. However, this processed meal has a lower nutritional value than whole corn meal.

There is interest in some developing countries to make bread from milled, degermed corn flour. This interest is because

wheat products have been growing in popularity with higher incomes, even in countries where wheat is not a suitable crop to grow. The rising demand for wheat products then results in increasing wheat imports, a problem for countries facing a foreign exchange shortage. The Nigerian Government, for example, is attempting to require its millers to mix corn flour (up to 10 percent) with wheat flour for bread following a ban on wheat imports. However, because the gluten in corn does not have the elasticity of wheat gluten, bread made with corn flour crumbles easily. It also becomes stale quickly. Thus, this bread is not very acceptable to consumers.

Latin Americans, however, have long used masa corn flour to make tortillas. Masa flour is not just milled corn flour. First, the corn kernels are cooked in water and lime for about a half hour. After standing overnight, the water is thrown out and the corn washed to remove some of the lime. This cooked corn, called nixtamal, was traditionally ground by hand into masa flour to make tortillas. Today, machines are used in the villages and towns to grind the nixtamal.

In the large urban areas masa flour is now produced by large manufacturers using recently developed technology (10). Fresh

White corn production and use in selected countries

Country	White corn's share of total corn production 1/	Total calories in diet supplied by all types of corn 2/
	Percent	
Africa:		
Egypt	100	19
Benin	90	24
Ghana	90	13
Ivory Coast	100	10
Nigeria	90	6
Angola	100	21
Cameroon	95	15
Zaire	100	9
Ethiopia	100	18
Kenya	100	44
Somalia	100	19
Tanzania	100	24
Uganda	100	14
Malawi	100	65
Mozambique	100	19
Zambia	100	53
Zimbabwe	100	55
South Africa	50	33
Latin America:		
El Salvador	90	37
Guatemala	80	48
Honduras	95	45
Mexico	90	37
Argentina	5	1
Bolivia	35	14
Brazil	2	8
Colombia	50	12
Paraguay	50	20
Peru	35	10
Venezuela	80	15
Asia:		
India	40	4
Indonesia	25	8
Pakistan	55	3
Philippines	90	17
Thailand	0	1
United States	2	2

1/ Source: (4), except for South Africa, which is (11).

2/ For 1975-77 (2).



Coarse grain imports of higher-income LDC's

Country	Corn	Sorghum	Barley
	Percent 1/		
Asia:			
South Korea	15	6	-- 2/
Taiwan	15	10	4
Malaysia	5	--	--
Hong Kong	2	--	--
Singapore	2	--	1
Latin America: 3/			
Mexico	11	43	--
Venezuela	4	13	--
Brazil	7	--	2
Africa and Middle East: 4/			
Saudi Arabia	3	--	54
Algeria	2	5	4
Iran	3	--	6
Jordan	--	--	2
Syria	1	--	2
Libya	1	--	3
Kuwait	--	--	2
Israel	1	10	3
Iraq	2	--	4
Total	100	100	100

1/ Percent of developing countries' total imports of commodity in 1983-85. 2/ -- = Less than 1 percent. 3/ Argentina, Chile, Panama, Trinidad, and Uruguay, each accounts for less than 1 percent. 4/ Oman and South Africa each accounts for less than 1 percent. Egypt is not listed because it is not classified as a higher-income LDC.

tortillas can then be prepared within a few minutes in the home. Consumers can also buy fresh tortillas from local manufacturers. Urban consumers want foods that are quick and convenient to prepare.

Despite the availability of improved corn products, CIMMYT finds no significant statistical relationship, in aggregate, between the rise in per capita income in developing countries and use of corn directly as food (8). Per capita food use of corn has been relatively constant across developing countries the past two decades. With rising incomes and urbanization, people tend to increase their consumption of grains such as wheat and rice, and importantly, meat. Studies have shown a strong, positive relationship between per capita income and the use of corn as feed to raise the livestock and poultry needed to supply the demands of consumers with rising incomes (8, 9). Once incomes are high enough for consumers to have the disposable income to upgrade their diet with meat products, the demand for livestock products and feeds increases rapidly.

### *Feed Use of Corn*

Over two-thirds of the grains used for feed in the developing countries are fed to poultry and swine (8). Growth of broiler production has been particularly strong, with more feed-efficient birds, intensive poultry production units and associated feed manufacturing. Egg production has also expanded rapidly in the developing world with the introduction of intensive production methods.

Yellow corn is often preferred to white corn, and sorghum as well, for poultry feed because of its carotene content. This carotene gives the egg yolk and the skin of the poultry meat the yellow color preferred by many consumers.

The growth in pork production in developing countries, although less rapid than poultry meat and egg production, has also boosted demand for grains. Swine use more grain per unit of output than poultry. Under good conditions 5 to 6 kilograms of feed are

required to produce 1 kilogram of pork, and only 2 to 3 kilograms to produce 1 kilogram of poultry meat.

Rising incomes in the higher-income countries quickly raised per capita use of corn for feed during the 1960's and 1970's. However, when incomes dropped off in the 1980's, use of corn for feed also fell. Feed use of corn in low-income countries has remained low and flat during the past 25 years (13). In comparison, wheat consumption also rose and fell with income in the higher-income countries, but not at the same pace.

#### *Prospects For Continuation of Trends*

Generally, corn imports by developing countries appear unlikely to be offset by widespread increases in domestic production due to improved varieties, as with the Green Revolution for wheat in the traditional spring-wheat-growing countries during the late 1960's and 1970's. However, the slower economic growth in those developing countries facing a debt crisis has jeopardized continuation of corn import trends.

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## HYBRIDS INCREASE SORGHUM PRODUCTION IN DEVELOPING COUNTRIES

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**Abstract:** Since the early 1970's, sorghum production has been increasing rapidly in the developing countries, accounting for one-fourth of the total increase of coarse grain there. The increased sorghum output is primarily due to the rapidly expanding area planted to high-yielding, hybrid varieties in Latin America. Hybrids are also increasing yields in Asia, but production has been static because area is declining. The use of hybrids in Africa is negligible, and average yields have been trending down for 25 years.

**Keywords:** Sorghum, hybrid sorghum, green revolution, developing countries, coarse grains.

Sorghum represents only 4 percent of the world grain production of some 1.7 billion tons (1982-84), and an even smaller share of the grain trade. Yet it is of crucial importance in many parts of the world. It is the most important food grain in the Sahel and other arid and semi-arid areas of Africa, where living standards depend to a large extent on sorghum production. It is mostly a food grain in India, and a principal feed grain in Central and South America.

### Sorghum in the Developing Countries

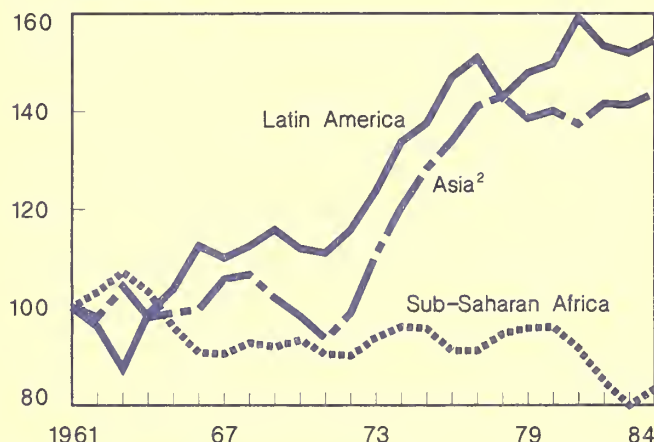
The developing countries produce about half of the world's sorghum, most of which is consumed in the country in which it is grown. Only two developing countries, Argentina and Mexico, consistently trade large volumes of sorghum. In 1983-85, Argentina had 86 percent of all developing-country exports of grain sorghum and was the principal U.S. competitor. Mexico had 43 percent of the developing countries' grain sorghum imports, and is a key U.S. market.

### *Sorghum Production Widespread*

Grain sorghum production in the developing countries is almost equally divided among three regions: Asia, Sub-Saharan Africa, and Latin America. (The People's Republic of China is not included in this discussion.) Most of Asia's production is in India, the world's second largest sorghum producer after the United States. Argentina

### Hybrids Raise Yields in Latin America and Asia<sup>1</sup>

% of 1960-62



<sup>1/</sup> Three-year averages centering on dates shown.  
<sup>2/</sup> Does not include PRC.

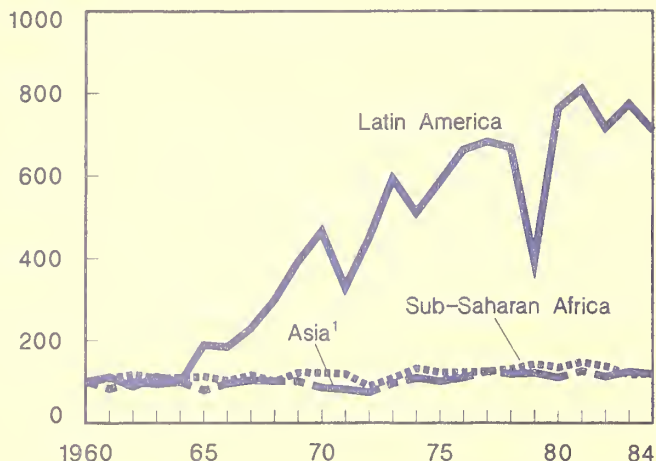
and Mexico produce most of the Latin American sorghum. Sorghum is widely grown in the semi-arid areas of Sub-Saharan Africa. Nigeria is the major producer, followed by Sudan and Ethiopia. Little sorghum is grown in North Africa and the Middle East.

Latin American yields are high, and along with area, are increasing. Yields in India are rising because of hybrids, but area is declining. In Sub-Saharan Africa, expanding area is offset by declining yields. See Roth and Abbott (9)\* for country-level production and trade data for the world.

\* Numbers in parentheses refer to literature cited at the end of this article.

## Sorghum Production Increases Rapidly in Latin America

% of 1960



1/ Does not include PRC.

## Sorghum Used as Food

Most of the sorghum grown in the LDC's of Africa and Asia is consumed as food by low income, rural people. The stalks, which may reach 15 feet, and leaves of the traditional varieties are used for feed, construction material, and fuel. In Asia, about 85 percent of the sorghum is used as food as is 95 percent in Africa. In contrast, almost 95 percent of the sorghum use in Latin America is as feed.

Sorghum is used for many types of food in Asia, Africa, and Latin America (8). For example: Indian roti is an unleavened bread. In Central America, the tortilla is an unleavened bread usually prepared from corn; however, in some countries such as Honduras and Guatemala, sorghum or blends of sorghum and corn are used. In Sudan, kiswa is a leavened bread made from sorghum. Ogi in Nigeria is a porridge made by soaking sorghum grain in water at room temperature for 2 to 4 days to soften the kernels and to ferment. The fermented sorghum is milled with large quantities of water and then filtered through a sieve. The filtrate is allowed to settle. The sediment is ogi. Sorghum is also widely used to make beer.

Unlike the other major cereals, underneath the hull of most traditional sorghums is a layer called testa that contains high levels of tannin. Tannins are distasteful to weaver birds, the most destructive sorghum pest in Africa. Large colonies of these birds

can quickly devastate a maturing crop. If there are alternative foods available, usually grass seeds, the birds will not bother sorghum with tannins. If these sorghums are prepared for consumption without first removing the testa layer, the tannin will combine with the proteins in mature grain, making it nutritionally unavailable to humans and monogastric livestock, such as poultry and swine. The tannins also reduce the incidence of molds if mature grain is not harvested immediately. Traditionally, hulls have been removed by hand pounding, taking up to 1 hour to process 2 kilograms of grain.

Analysis of income and consumption data in the developing countries suggests that the use of sorghum as food declines as income increases. However, because rising incomes generally stimulate a higher demand for livestock products, researchers find a positive relationship between income and the use of sorghum as a feedstuff (9).

## Sorghum Suited for Semi-Arid Climates

Sorghum is suited for semi-arid climates because it is more tolerant of hot, dry weather than corn and has higher yields than millet, a crop even more tolerant of dry weather. Sorghum is best suited for the heavier soils of the semi-arid tropics. Millets are better suited for the light sandy soils. There will always be extensive areas of the rain-fed tropics where sorghum and millet will be the main cereal crops because they will give more consistent yields under semi-arid conditions.

## Hybrid Adoption Slow in India

In a joint project of the Indian Agricultural Research Institute and the Rockefeller Foundation in the 1960's, semi-dwarf sorghum hybrids with yields 60 percent higher than traditional varieties were made using U.S. male sterile lines. When growing these hybrids, farmers typically shift from intercropping with traditional varieties to sole cropping and more intensive management, including fertilization, to realize the higher yield potential. Because of the increased risk when using additional inputs, the use of hybrids has been limited to the sorghum growing areas with more dependable rainfall or that can be irrigated. These hybrids now occupy one-third of total sorghum area, raising average yields in the country.



Sorghum hybrids and traditional varieties are readily differentiated in the market and are priced accordingly. The grain from hybrids is priced lower than traditional sorghums because of its poorer quality for roti making. And, unlike the traditional varieties, the stalk of semi-dwarf hybrid varieties is considered to lose its feed value after drying; only negligible quantities can be sold in the local markets.

Important factors underlying the decline in sorghum area in India include a consumer preference for wheat and rice, little demand for sorghum grain for feed, and a lack of government promotion through price supports, extension, etc. Sorghum area also declined due to the green revolution for wheat. When farmers in the dryland areas invest in irrigation facilities, they often switch to the more profitable high-yielding, semi-dwarf wheat (7).

#### *Research Growing in Africa*

The American and Indian hybrids cannot be grown in Africa because they are not resistant to local diseases and pests. The American hybrids were developed for livestock feed, not human tastes. Improved varieties developed in Africa have not replaced traditional varieties because of difficulties with germination and seedling establishment, grain quality, and not fitting the intercropping practices of subsistence farmers. In addition, the new, high-yielding hybrid sorghums are semi-dwarf (up to 6 feet in height) and thus, the stems and leaves are not nearly as useful for feed and building material as traditional varieties (1).

The French began research in West Africa in 1931 to develop suitable high-yielding sorghums, but the failure to achieve any noticeable improvement in yields in over 40 years partially explains why Sahelian countries asked the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to set up a sorghum and millet research program in the Sahel in the mid-1970's (2). The U.S. Agency for International Development's (USAID) Collaborative Research Support Program on Sorghum and Pearl Millet (INTSORMIL) is also contributing to the effort. Researchers are now making progress. Recently, for example, a promising new hybrid sorghum was released in Sudan

after a 12-year research program in which 5,000 varieties were tested. This new hybrid, Hageen Dura-1, has produced average yields 52 percent higher than local varieties over four crop seasons at an experiment station (3). In Africa, as in India, the hybridization of sorghum has been carried out using male sterile lines from the United States.

Development of high-yielding hybrids, however, will not entirely solve the problem of how to intensify sorghum production in Africa. Yields of many varieties are presently below their potential because of various pests and diseases. For example, sorghum yields can be reduced as much as 80 percent by the parasitic witchweed, which becomes a severe pest if sorghum is grown without rotation. Extensive areas in Africa have been rendered unfit for sorghum cultivation, with the buildup of witchweed under continuous sorghum cultivation (10). The parasite's seeds remain viable in the soil for more than 10 years. It is almost impossible to control mechanically and few sorghum varieties have resistance.

Even in those areas where sorghum is better suited, corn may still be grown because it is a preferred food and because it is better protected against grain-eating birds. Corn is also more convenient and easier than sorghum to prepare for consumption. Thus, a cash market developed during colonial times for corn while sorghum remained in the informal, subsistence economy.

To move sorghum out of this subsistence economy several things are needed, including improved processing. Before grinding into flour, the sorghum is hulled manually, using a pounder and a little water to make it easier to remove the seed coat. Even though the flour is left to dry after grinding, it will still contain 30 percent water. Because flour prepared in this way turns rancid very quickly, it must be used within 2 days. Researchers are developing mechanical dry dehullers. The flour made after dry hulling can be stored for months.

These developments could make sorghum flour a more marketable product in the rapidly growing urban areas which have become dependent on imported wheat and rice. Dry mills, designed specifically for dehulling and milling sorghum, can decrease the tedious hand processing time, the flour moisture

content, and the amount of hull in sorghum flour—all essential for development of the cash markets that can provide the incentives for farmers to intensify rain-fed sorghum production.

### Feed Sorghum Expanding In Latin America

Following the development in the United States of high-yielding hybrid feed sorghums that could be machine harvested, strong interest developed in Latin America. Starting in the 1960's, U.S. seed firms began marketing hybrid seed in Latin America, where it grew very well, and area expanded very rapidly.

#### *U.S. Research Beneficial*

Sorghum has greatly changed since it was introduced in the United States in the 1850's. The tall, late-maturing daylength-sensitive varieties from Africa were transformed into semi-dwarf, early-maturing varieties that are not sensitive to daylength. Many of these varieties produce grain with no tannin, and are referred to as yellow sorghums. The U.S. sorghums with tannin are called brown sorghums. The U.S. grain sorghums are no longer dual purpose plants supplying both grain and forage, as in Africa. (The United States has also developed specialized forage varieties.) Shortening the plants permitted mechanized harvesting. The daylength insensitivity increased the crop's adaptability.

Because the feed value of yellow sorghums is almost equal to corn, they receive a higher price than the brown sorghums. Brown sorghum grain causes a 10- to 30-percent reduction in feed efficiency, compared with yellow sorghum (5). There is a dock of about \$1 per hundredweight for brown sorghums, so there is very little grown in the United States. The brown sorghums that are grown are not mixed with the yellow sorghums that the United States exports. Other exporting countries including Argentina and Sudan, however, do not keep their sorghums separated, which causes potential U.S. customers to think that all sorghums are nutritionally inferior.

In the 1950's, commercial high-yielding hybrid sorghums were developed by publicly supported breeding programs. Because sorghum is a self-pollinating crop, producing

hybrid sorghum on a commercial scale was not possible until the discovery of cytoplasmic male sterility (CMS) in the early 1950's. Self-pollination can be prevented by CMS, a factor inherited through the cytoplasm that prevents viable pollen from being produced.

#### *U.S. Firms Market Hybrids*

Yield trials, largely encouraged or conducted by U.S. companies, in Mexico, Argentina, Australia, and South Africa showed that U.S.-bred feed sorghum hybrids performed well, while in contrast, U.S. hybrid corn was not so directly transferable. The U.S. seed companies quickly established themselves in Argentina and Mexico, countries with large, semi-arid areas.

In Mexico, sorghum was introduced in the irrigated cotton areas of the Northwest. The Mexican farmers were soon obtaining yields equal to or higher than in the United States and production increased rapidly. Sorghum was a more efficient user of irrigation water than cotton or rice. Because sorghum uses the same planting and harvesting machinery as wheat, a wheat-sorghum rotation was established (6). Sorghums supply Mexico's rapidly growing poultry and swine production.

Mexico's sorghum imports have become the largest in the developing world even though production has increased rapidly. Had it not been for the development of sorghum production, either massive feed grain imports would have been necessary, or the poultry business could not have grown so fast.

In Argentina, sorghum varieties suitable for combine harvesting were already being planted in some of the drier areas. With the introduction of hybrids (mostly produced by local licensees of U.S. seed companies) production expanded as both planted area and yields increased (6). In Argentina, sorghum is primarily grown for export. Importantly, most of the Argentine sorghum has tannins, making it less competitive in international markets with corn and with the yellow sorghums exported from the United States. Recently, sorghum area has declined because of competition from sunflowers, which give a higher income (4).



## Food Use Small in Latin America

In recent years, there has been increased interest in growing sorghums suitable for direct human consumption. In areas with considerable risk of drought, an early-maturing corn crop is intercropped with a traditional, long-season sorghum (12). In good years, corn is used for the family and sorghum for poultry and livestock, but in dry years, when the corn crop fails, sorghum is used in the tortillas. The area in traditional sorghums is small compared to feed sorghums. However, because sorghum is better suited than corn to some of the drier areas in Latin America, plant breeders are now breeding higher-yielding food sorghum varieties. These provide new possibilities for supplementing cereal production for human consumption in areas where corn yields are poor due to uncertain rainfall.

### Limited Impact on U.S. Exports

U.S. research has meant a green revolution for sorghum yields in parts of the developing world. This is most evident in Latin America, where U.S.-developed hybrids were used directly, and in India, where high-yielding hybrid varieties were developed from U.S. CMS lines. Although a sorghum green revolution has not occurred in Africa, development of suitable hybrids is gaining momentum and research on mechanized milling is progressing. The impact of hybrid varieties on sorghum production in the developing world has been much less than the green revolution for wheat.

Except for Argentina, which will continue to be a low-cost sorghum exporter, this green revolution has not adversely affected the U.S. export market. Sorghum in Africa and Asia is mostly consumed as food by low-income, rural people. U.S. feed sorghums are not suitable for their needs. Production has increased in Mexico, but not nearly as rapidly as the feed requirements for the livestock sector. Mexico is already a key market for U.S. sorghums with further developments from the private sector. Presently, however, economic stagnation and massive debts limit Mexico's imports.

Mexico is one of the upper-middle income countries, which has been the driving force in shifting the developing world from net exporters of coarse grains to net importers(13).

Consumers in these upper-middle income countries are including more meat and poultry products in their diet. This demand, arising from higher incomes, is increasing the requirements for feedstuffs much faster than domestic production. Shortfalls deriving from this imbalance are creating strong, growing markets for coarse grains such as sorghum.

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## RESEARCH AND DEVELOPMENT AFFECTS U.S. AND THIRD WORLD SOYBEAN TRADE

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**Abstract:** A historical view shows that U.S. dominance of world soybean trade, founded on U.S. research and development in the 1940's and 1950's, declined in the 1980's as the South American countries, spurred by high prices, developed large-scale production and processing facilities. Their success, mainly in temperate areas, has not been duplicated in tropical areas elsewhere in the Third World. In most Third World countries, economic development and rising incomes have raised the use of soybean products above local production, with the result that imports are increasing.

**Keywords:** Soybeans, agricultural research, production, processing, trade, United States, Brazil, Argentina, Third World.

Soybean production was dominated by China in the 1940's when U.S. plant breeders set to work to redesign the soybean plant to make it suitable for mechanized harvesting and U.S. growing conditions. U.S. investment in efficient technology for extracting oil from the soybean seed and processing to prevent the oil from developing undesirable off-flavors made it a useful and low-cost edible oil. U.S. research in livestock and poultry feeding using soybean meal combined with rising demand for meat and poultry products to create large markets for soybean meal in the United States and overseas, especially in Western Europe and Japan. U.S. production and exports dominated these markets.

During the early 1970's, high soybean prices encouraged first Brazil and then Argentina to greatly expand large-scale soybean production and processing for export. As these countries offered lower prices to buyers, the United States had to begin sharing its markets with them in the 1980's.

The United States soybean sector has also had to compete with palm oil from Malaysia and Indonesia. The low production costs of new, high-yielding varieties that doubled yields have made the Asian palm oil industry very profitable. In Malaysia, there was a large switch in the private sector to oil palm cultivation on land which had previously been used for rubber. In Indonesia, the main development of oil palm has been on publicly-owned lands.

These two countries have replaced Africa as the main supplier of palm oil. This expansion of palm oil in Southeast Asia was assisted by loans from international lending institutions such as the World Bank. Malaysia

Table 1--World soybean production, 1983-85 average

Group and country	Production	Harvested area	Yield
	1,000 tons	1,000 ha	Tons/ha
Developing countries:	25,986	15,518	1.67
Brazil	16,190	9,237	1.75
Argentina	5,983	2,820	2.10
Indonesia	707	778	0.90
India	687	950	0.71
Paraguay	673	440	1.51
Mexico	567	350	1.62
Republic of Korea	238	185	1.28
Thailand	179	162	1.08
Egypt	157	58	2.76
Colombia	107	55	1.93
Iran	102	54	1.90
Zimbabwe	85	54	1.62
Bolivia	71	45	1.59
Nigeria	58	190	0.31
Turkey	47	25	1.85
South Africa	31	29	1.10
Ecuador	29	17	1.60
Burma	21	29	0.74
Uruguay	14	10	1.36
Taiwan	10	6	1.63
Zambia	10	8	1.27
Philippines	8	8	0.96
Guatemala	5	3	1.60
Peru	2	1	2.00
Pakistan	2	3	0.58
Developed countries:	52,832	27,334	1.93
United States	51,591	26,720	1.93
Centrally planned economies:	10,700	9,065	1.18
China	9,495	7,757	1.70

Source: (12).

now supplies over three-quarters of world palm oil exports. Indonesia supplies 15 percent of the market.

Still more competition for U.S. soybeans is now arising in the European Community (EC), which has been using high price supports since the mid-seventies to encourage its farmers to grow more rapeseed, sunflowers, and soybeans. Production of rapeseed and sunflowers, two oilseeds especially well suited to the climate of Western Europe, is increasing. The competition among the United States, Brazil, and Argentina may become even more fierce if the EC continues to follow present policies and is able to reduce its imports substantially.

This international trade competition is prompting U.S. soybean producers and processors to search for new markets, including countries of the Third World. Economic development and population growth in the Third World are raising the demand for edible oils and for protein supplements for feeding livestock and poultry. To gain a large share of these growth markets the United States will have to be price competitive.

*U.S. Research and Development Created A World Market for U.S. Soybeans*

Early this century, Manchuria, a province of China, was the principal exporter of soybeans to the world and the United States. The beans imported into the United States were processed into oil and meal with hydraulic pressing. U.S. farmers did grow some soybeans, but mostly for hay and green manure, not seed for processing.

Growing soybeans for processing expanded in the United States after the introduction of efficient solvent extraction technology from Germany in the 1930's. The solvent extraction process removes almost all the oil, leaving 1 percent or less of residual oil in the meal. Early oil extraction by pressing produced oil and press cake containing 3.5 percent or more of residual oil. With the improved technology, a soybean seed processing industry developed and a market was created for soybeans grown for seed. By 1941, the area of soybeans grown for processing into oil and meal exceeded that for hay and green manure.

Soybean planted area expanded rapidly in the United States during the 1940's and 1950's as breeders developed new varieties. The

Table 2--Net imports by developing countries 1/

Country	Soybeans	Soybean--	
		meal	oil
		1,000 tons	
Mexico	1,314	103	47
Republic of Korea	739	189	0
Israel	443	-5	14
Malaysia	169	145	-13
Venezuela	107	576	85
Saudi Arabia	31	110	6
Hong Kong	18	98	2
Iran	17	315	353
Singapore	13	83	8
South Africa	4	159	11
Iraq	3	167	1
Chile	0	31	87
Algeria	0	162	10
Higher-income countries	2,871	2,376	664
Taiwan	1,366	-3	2
Indonesia	374	169	5
Colombia	107	10	68
Egypt	49	222	45
Turkey	29	2	93
Philippines	18	273	4
Morocco	15	2	126
India	0	-275	581
Pakistan	0	6	260
Thailand	-1	218	27
Paraguay	-562	-49	0
Lower-income countries	1,617	764	1,706
Argentina	-2,475	-2,343	-447
Brazil	-1,912	-8,103	-836
Developing countries	101	-7,004	126

1/ The countries listed had net imports greater than 75,000 tons. The subtotals for higher- and lower-income countries are greater than the countries shown because the countries with less than 75,000 were included in the summation.

Source: (12).

varieties made available before the 1940's were Asian. In particular, the varieties grown in Manchuria had a suitable daylength for the Midwest. After the 1940's, soybean breeders began crossing these introductions from Asia to create new, improved varieties that were more disease-resistant and did not shatter as easily when harvested mechanically. It was only through the development of new varieties that soybean production could become widespread in the lower Mississippi Valley and the southeastern United States (5). 1/

1/ Numbers in parentheses refer to References at end.



Reduced shattering during harvesting was important for mechanized U.S. farmers. Asian farmers had developed varieties that shattered easily because they cut the plant by hand just before maturity and carried it to the village for drying. Varieties that shattered easily during manual threshing were desirable. However, this trait resulted in high field losses for U.S. farmers who let their crop mature and dry in the field before harvesting with machines.

Despite varietal improvements, soybeans remained a relatively minor crop until U.S. consumers experienced shortages of butter during World War II. Once soybean oil started going into the manufacture of margarine, U.S. soybean production doubled.

*Soybean oil.*—Although partially refined soybean oil became an important edible oil in the United States in the late 1940's in shortenings and margarines, when it was refined further to meet the more stringent requirements for salad oil uses, problems arose. Unlike some competing oils, highly-refined soybean oil developed an unacceptable beany flavor shortly after processing.

The flavor of an edible oil is influenced by its fatty acid composition. The fatty acid composition of soybean oil is approximately 10 percent linolenic, 30 percent oleic, and 55 percent linoleic acid. When linolenic acid is broken down by enzymes or by spontaneous oxidation, a beany flavor develops. Researchers discovered how to convert linolenic to linoleic or oleic acid (hydrogenation). Using this process to reduce linolenic content to less than 2 percent solved the flavor problem, and soybean oil use expanded quickly in the United States and elsewhere.

The 1950's shift in consumer preference to unsaturated fats and oils further increased the demand for soybean oil. This increased processing of soybeans for oil greatly expanded the supply of soybean meal for the livestock industry.

*Soybean meal.*—Soybean meal use was accelerating by the mid-1950's with the spread of intensive livestock feeding in the United States, Western Europe, and Japan. This increased use of meal was possible

because researchers had discovered how to utilize soybeans as a protein supplement.

Soybean meal has not always been a useful protein supplement. Prior to 1930, animal products, not plant products, were the protein supplements in livestock feeds. Scientific discoveries and new technology changed this. First, researchers learned that heating soybeans would destroy trypsin and other growth inhibitors that are present in raw soybeans. For example, heating the soybeans doubled the efficiency of its meal to promote poultry growth (1).

Soybean meal was then used to substitute for part of the animal proteins in livestock rations. In the late 1940's researchers discovered that it was the vitamin B12 in animal products that made them better protein supplements than soybean meal. With the discovery of how to synthesize B12, livestock and poultry rations with manufactured B12 could be formulated using soybean meal as the primary protein supplement.

The rise of soybean meal to the major protein supplement can be seen in the changes in the typical rations of the U.S. broiler industry. In the 1930's, broiler rations contained no soybean meal (1). By the mid-1940's, typical rations contained 5 percent soybean meal. Now, broiler rations generally contain 30 percent soybean meal.

Table 3--Comparison of relative feeding value of soybean meal

Oilseed meal	Feeding value for--		
	Poultry	Swine	Cattle
	Index 1/		
Soybean meal	100	100	100
Coconut meal	50	50	90-100
Cottonseed meal	85	85	100
Linseed meal	80	80	95
Peanut meal	95	95	100
Rapeseed meal	80	85-90	88
Safflower meal	45-50	45-50	40-45
Sunflower meal	95-100	90-95	95-100

1/ Relative feeding value pound for pound with soybean meal (41 percent protein) used as the base = 100.

Source: (2).

Through the 1960's the United States dominated world soybean trade. This dominance began to decline as soybean production expanded rapidly in South America, first in Brazil and then in Argentina. These countries have focussed on trade in soybean products as multinational companies have established large-scale, modern processing facilities in their countries.

*Brazil.*— Soybean production began to expand in the 1950's as a substitute for other crops in the established farming areas of southern Brazil. Brazilians were able to use commercial varieties from the southern United States because growing conditions are similar. Production continued to expand in southern Brazil during the 1960's and into the 1970's as farmers began double-cropping soybeans with wheat.

Soybean output continued to increase through the late 1970's and the 1980's as virgin lands in central and west-central Brazil were opened for production. This opening of new lands accelerated with, among other things, the high international prices for soybeans during the first half of the 1970's. Expansion into these subtropical and tropical areas was possible because Brazilian breeders had developed suitable new varieties.

Expanding soybean production along the country's agricultural frontier required huge investments for rural transportation, a problem because of a shortage of capital. This problem was eased during the 1970's with foreign investments (notably from Japan) through Brazil's Export Corridors Program (10). Improved transportation reduced the costs for the inputs needed to grow soybeans and for shipping soybeans for processing and export.

Brazilian exports increased rapidly, especially meal because the Government set export quotas and taxes to favor exports of processed products over soybeans. The Government also provided low-cost financing to build processing facilities (6).

The Brazilian oilseed processing industry, formerly based on small family-owned plants

for cottonseed, peanuts, and castor beans, now includes modern soybean processing facilities. These newer plants process 1,500 tons or more per day, enough to achieve the same economies of size as in the United States. Multinational firms helped transfer this technology to Brazil. By the late 1970's, more than one-third of Brazil's soybean processing capacity was owned by multinational companies (12).

Although the Brazilian soybean sector has grown more slowly in the 1980's than during the previous decade, Brazil remains an important exporter. It has large areas of virgin land and a new program to continue upgrading its internal transportation system (12). Expansion will likely depend on international soybean prices and the availability of capital for rural transportation investments. Currently, international prices are low compared with the boom years of the 1970's, and the country's debt crisis limits the availability of investment capital. Thus, the medium- to long-term prospects for increased soybean output are favorable, but not as good as during the early 1970's.

*Argentina.*— The rise of soybeans in Argentina from the mid-1970's was just as dramatic as in Brazil. Argentine farmers greatly increased soybean production even though there has been little increase in total grain and oilseed acreage since the 1930's. The greater soybean production resulted from the shift to double-cropping of soybeans with wheat already being grown. As in Brazil, southern U.S. commercial varieties were used because conditions are similar.

Recently, farmers have been dropping wheat and raising just soybeans as a single crop in order to boost soybean yields. The low prices for wheat have reduced its profitability. In 1985/86 and 1986/87, single-crop soybeans were 50 percent or more of the soybean acreage, compared with 30 percent several years before (12). Argentine farmers have also recently been substituting soybeans for corn because of their greater profitability.

Near-term prospects for area increases through substitution for other crops will depend on soybean prices, particularly relative to corn prices. In the longer run, expansion of soybean production into the drier areas of the



### Principal Soybean Traders, 1935-39



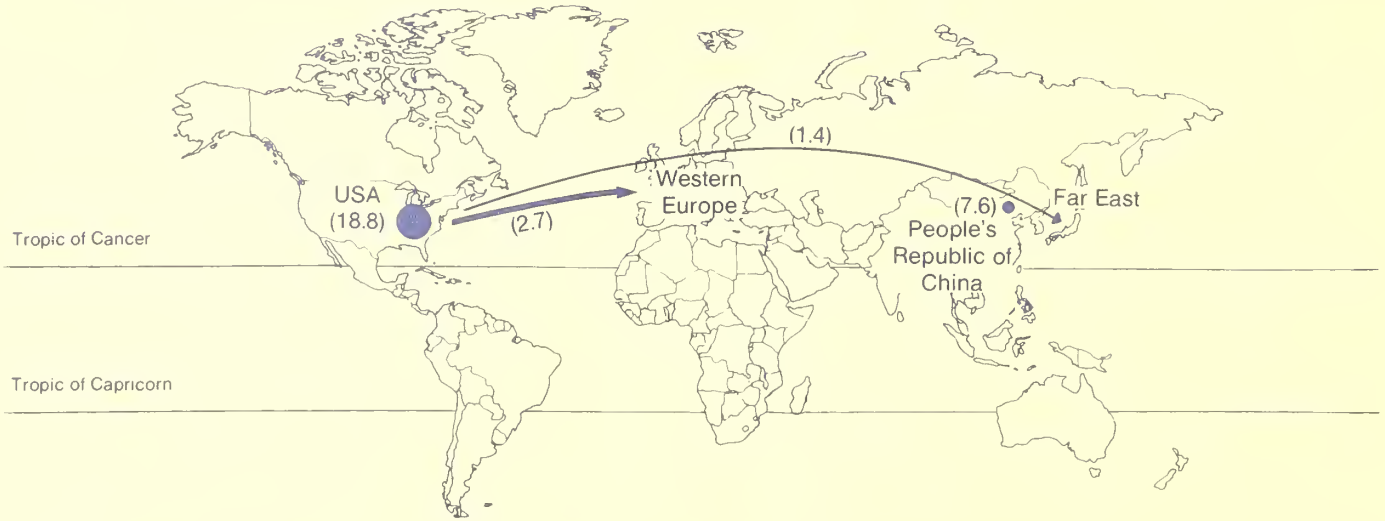
Arrows, representing trade, are strictly proportional to volume.  
Figures in parentheses represent aggregate tonnage in millions of soybeans and soybean products, annual averages.  
Source: U.S. Senate, Committee on Agriculture and Forestry, "Foreign Trade in Agricultural Products" (Washington, DC: GPO, 1953).

### Principal Soybean Traders, 1950-51



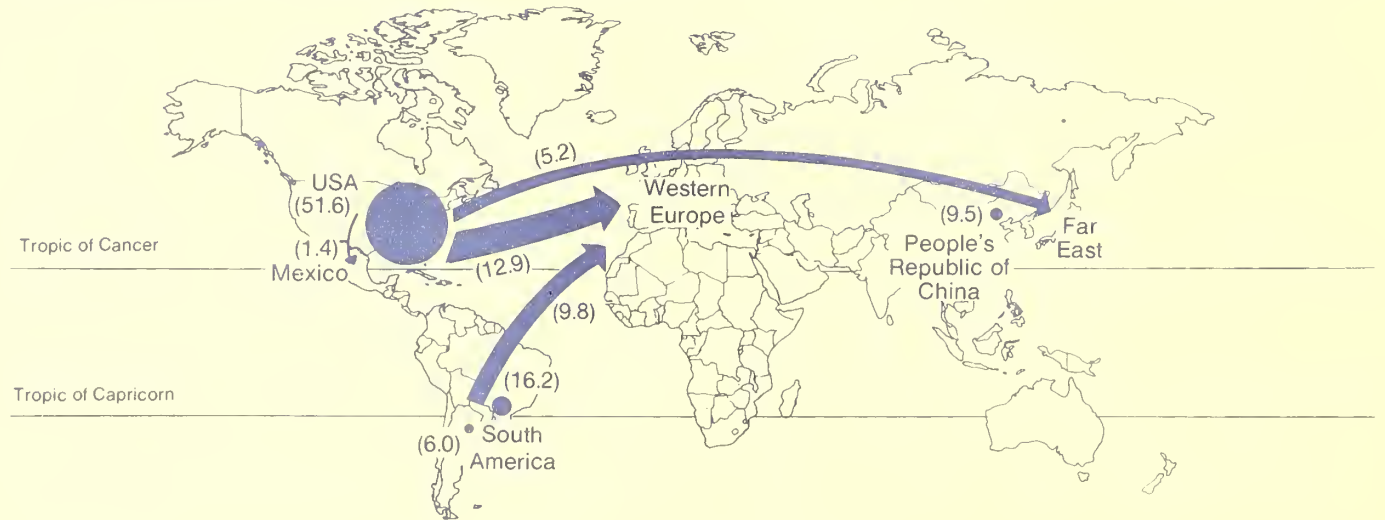
Arrows, representing trade, are strictly proportional to volume.  
Figures in parentheses represent aggregate tonnage in millions of soybeans and soybean products, annual averages.  
Source: U.S. Senate, Committee on Agriculture and Forestry, "Foreign Trade in Agricultural Products" (Washington, DC: GPO, 1953).

**Principal Soybean Producers and Traders, 1962-64**



Circles, representing production, and arrows, representing trade, are strictly proportional to volume. Figures in parentheses represent aggregate tonnage in millions of soybeans and soybean products, annual averages. Source: *Oil World*, "The Past 25 Years and the Prospects for the Next 25" (Hamburg: 1983).

**Principal Soybean Producers and Traders, 1983-85**



Circles, representing production, and arrows, representing trade, are strictly proportional to volume. Figures in parentheses represent aggregate tonnage in millions of soybeans and soybean products, annual averages. Source: Unpublished USDA data.



Table 4--Soybean production, area, and yield changes

	1965-67	1983-85	Growth rate	Annual increase	Country share	
					1965-67	1983-85
	--1,000 tons---		Percent	1,000 tons	----Percent---	
Production:						
World	32,470	89,920	5.7	3,192	100.0	100.0
United States	18,092	51,591	5.8	1,861	55.7	57.4
Brazil	611	16,190	18.2	865	1.9	18.0
Argentina	19	5,983	32.1	331	0.1	6.7
	---1,000 ha----		Percent	1,000 ha	----Percent---	
Area:						
World	25,948	52,319	3.9	1,465	100.0	100.0
United States	13,731	26,720	3.7	722	52.9	51.1
Brazil	512	9,237	16.1	485	2.0	17.7
Argentina	16	2,820	28.6	156	0.1	5.4
	---Tons/ha----		Percent	Tons/ha		
Yield:						
World	1.25	1.72	1.8	0.03	--	--
United States	1.32	1.93	2.1	0.03	--	--
Brazil	1.19	1.75	2.1	0.03	--	--
Argentina	1.14	2.12	3.4	0.05	--	--

-- = Not applicable.

Source: (12).

country will be slowed because yields will likely be lower than in the areas where soybeans are now grown.

Soybean processing in Argentina has expanded greatly in recent years because the Government has provided tax incentives to favor domestic processing over the export of soybeans. As in Brazil, the development of processing facilities has been aided by direct foreign investment by multinational grain trading firms, including some based in the United States (12). The six largest companies, all of which are also multinational grain trading firms, control about 45 percent of Argentine processing capacity.

#### *Technology Transfer to Tropics Is Slow*

Soybeans moved from East Asia to the United States, and from there to South America because of similar, temperate climates and daylength. Generally, attempts to grow soybeans in tropical areas have been less successful because conditions are quite different.

Soybean production is of interest in tropical countries for several reasons. Soybean products can be used to supplement protein-deficient diets. Soybean production is

also of interest in those countries importing large quantities of soybean or other oils to meet a rising demand for edible oils. A good example is India, the largest importer of edible oils in the world.

In those countries where consumers want more livestock products in their diets, the need for protein supplements raises the demand for soybeans for meal. Thailand is an example of a tropical country attempting to establish a soybean industry to supply its emerging livestock sector with domestically-produced soybean meal instead of imports.

The research effort to develop new varieties and growing practices for the tropics is illustrated by the experience of Brazil. Brazil has developed a soybean research organization with 300 full- and part-time scientists (12). This is a very substantial investment to expand soybean production into their tropics. Few developing countries are wealthy enough to devote so many scientists and the associated facilities and operating budgets to one crop. In comparison, the United States has about 350 people involved in soybean production research.

Suitable soybean varieties can yield well in the tropics under favorable conditions and

with good management practices, as has happened in Brazil. Generally, however, soybeans are grown under less than optimum conditions in the tropics of developing countries. In many cases the inputs, such as fertilizers and seed, are not available to developing-country farmers, and when they are, the price may be too high for input use to be profitable, or credit may not be available for the poorer farmers to afford them. Besides the need for better growing conditions, improved varieties are also needed.

It is difficult to transfer high-yielding U.S. varieties to the tropics because most soybean varieties adapted for U.S. conditions flower too soon to make adequate growth for good yields. Soybeans are very sensitive to daylength and this sensitivity determines the area of adaption of each variety (4).

Another difficulty with transferring U.S. varieties to countries in the tropics is that they are not compatible with the native rhizobia (the essential nitrogen-making bacteria that grow in soybean roots). Introduced varieties must be inoculated with the bacteria with which they are compatible just before planting. This bacterium, *Rhizobium japonicum*, is not widely available in tropical countries because it dies when exposed to high daytime temperatures. Many of the countries in the tropics lack the investment capital to acquire the facilities and equipment to produce, store, and distribute the rhizobia to farmers.

Poor seed germination is also slowing the expansion of soybean production in the tropics. Seed quality is lowered if the soybean seed is subjected to a rainy period and high temperatures just before harvest. In addition, traditional storage practices for corn, wheat, sorghum, and cotton seed do not work for soybeans. Soybean seed germination declines rapidly when stored unprotected in the warm, humid conditions of the tropics. The low and uncertain germination rate lowers yields because farmers will have difficulty achieving optimum population, a key to getting high yields. If the germination rate is lower than expected, the stand will be too thin and weed growth will reduce yields. If the germination rate is higher than expected, the stand will be too thick, and the plants will grow so tall that they lodge (fall over) easily, again reducing yields.

Where there is no winter season, high germination is difficult without storage facilities to keep seeds dry and cool. Traditional, farm-level storage will not protect seed soybeans adequately in the tropics. Because many developing countries lack the capital to construct such facilities, the high-quality seed needed if soybean production is to expand is not available.

Even if much improved varieties and good seed are made available, farmers will not be quick to expand production until processing facilities can be developed. Investors will not construct modern processing facilities when an area might have only a few thousand hectares of soybeans. A small solvent extraction plant may cost \$20 million to build and require more than 200 tons of soybeans a day to be economical (6). This is much more than is grown in many developing countries. If the crop yield was one ton and the plant operated 300 days a year, then 60,000 hectares would be required. However, even 200 tons is small by modern industry standards. To achieve economies of size, U.S. plants process 1,200 to 2,000 tons per day.

Because of the small scale of soybean production in most countries of the tropics, village-level hydraulic extraction technology costing from \$5,000 to \$50,000 is more practical (7). Small-scale facilities for producing soy milk and textured vegetable protein are also used. Low-cost equipment opens up soybean processing to small-scale entrepreneurs to develop markets for soybean oil and protein-enriched foods. This is a key step to gaining consumer acceptance where soybean foods are new and incomes are not yet high enough to afford meat and poultry products to improve protein-deficient diets.

#### *Soybeans Have Long Been An Important Food in the Orient*

Soybeans are an important protein source for more than a billion people in East Asia. Their traditional soybean foods are made by water extraction or by fermentation.

Soy milk is made by soaking and grinding dehulled soybeans, cooking in water, and filtering off the insoluble residues. The remaining liquid has nearly the same analysis as cow's milk and is cheaper to produce. One kilogram of dehulled soybeans can make 5



kilograms of soy milk with a 5-percent protein content. Besides being a lower-cost protein food than dairy milk, soy milk is acceptable for people who are allergic to the lactose in cow's milk. This soy milk can be used to make soy ice cream, soy yogurt, and other dairy-like products. When calcium sulfate is added to soy milk, a curd, tofu, is produced.

Among the fermented products, soy sauce is common. It is made by fermenting rice with soybeans or soybean meal. Miso is another fermented product made by blending cooked soybeans with steamed rice and salt water. It becomes a paste that is used as a soupstock, as a spread on bread, and as a flavoring agent. Other popular fermented food products include natto and tempeh, both made from small, whole soybeans.

Despite the popularity of these soybean foods in the Orient, gaining consumer acceptance in other countries is slow. In some, low-income people have protein-deficient diets. The low cost of Western soybean food products makes them potential supplements in protein-deficient diets. In India, for example, the cost per kilogram of protein in milk and eggs was 12 and 15 times higher than in soybean flour (13).

Researchers are experimenting with various ways of using soybean products to supplement the protein of the traditional starch foods in low-income areas. In Cameroon, for example, researchers are using soybean flour to fortify "fufu," a popular cassava food with a protein content of only 2 percent (8). The addition of 10 percent soybean flour raises the protein content to 7 percent without changing the taste.

Three general types of soybean food products can be made from the seed after the oil is removed (14). Flours and grits are the least refined forms and sell at the lowest prices. These products are 40 to 50 percent protein. Protein concentrate is a more refined product, with a protein content of at least 70 percent. Concentrates sell at three to four times the prices for flours and grits. Protein isolates are the most refined. Their protein content is greater than 90 percent and they are eight to ten times more expensive than the flours.

Flours, concentrates, and isolates are powders. They can be made into textured forms with fibrous, chewy properties resembling meats. These textured products sell for 1.5 to 2 times the prices of the powdered forms.

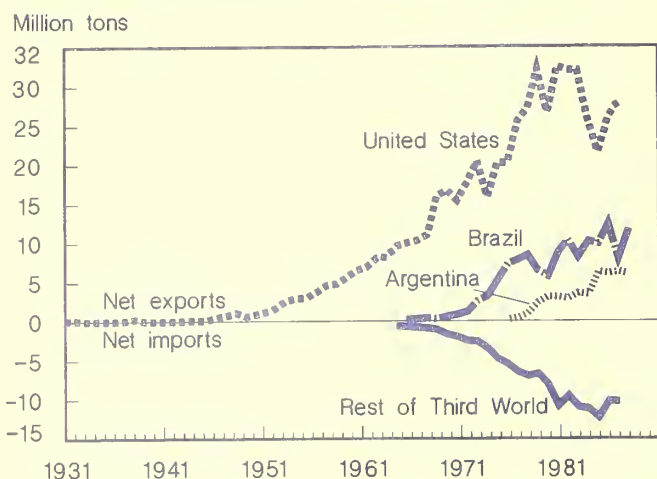
### *Expansion Will Continue If Prices Are High*

Where soybeans have the potential to supplement protein-deficient diets of low-income people, it will be important to gain consumer acceptance for soybean and soybean-fortified foods. Research will be needed to develop suitable varieties and investments will have to be made in facilities for seed storage and rhizobia production and distribution. Investments in small-scale processing facilities will also be needed.

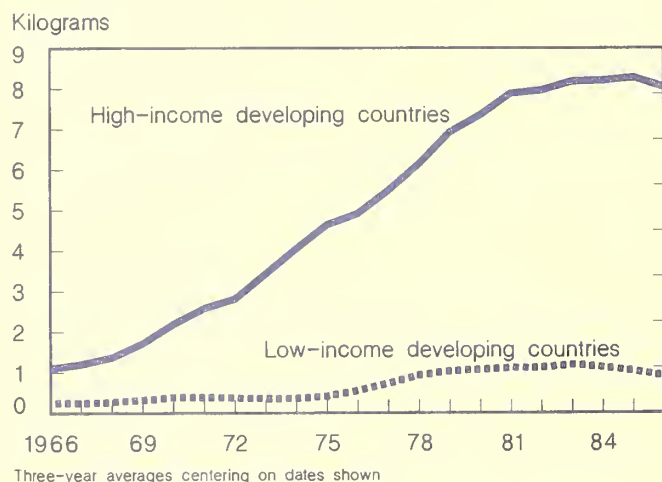
The major factors driving increased demand for imports of soybeans and soybean products in the Third World are rising incomes and population. Rising incomes raise consumer demand for meat and other food products such as margarine and cooking oil, in turn boosting the demand for meal and edible oils.

Fierce export competition with the South Americans for these markets, as well as the developed-country markets, will likely continue. The expansion of large-scale soybean production in South America will continue as long as soybean prices are high enough for Brazilian farmers to profitably open new lands for soybeans and the Brazilian Government to develop the rural transportation system connecting these lands to the ocean ports. If the price of soybeans is high relative to other crops, farmers in Brazil, Argentina, and elsewhere will find it profitable to switch even more of their existing cropland to soybeans.

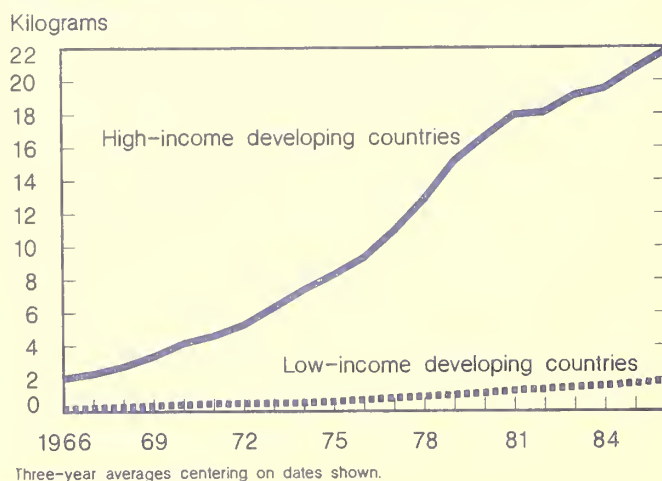
## Soybean and Soybean Product Trade of the United States and the Third World



## Per Capita Use of Soybean Oil



## Per Capita Use of Soybean Meal as a Protein Supplement



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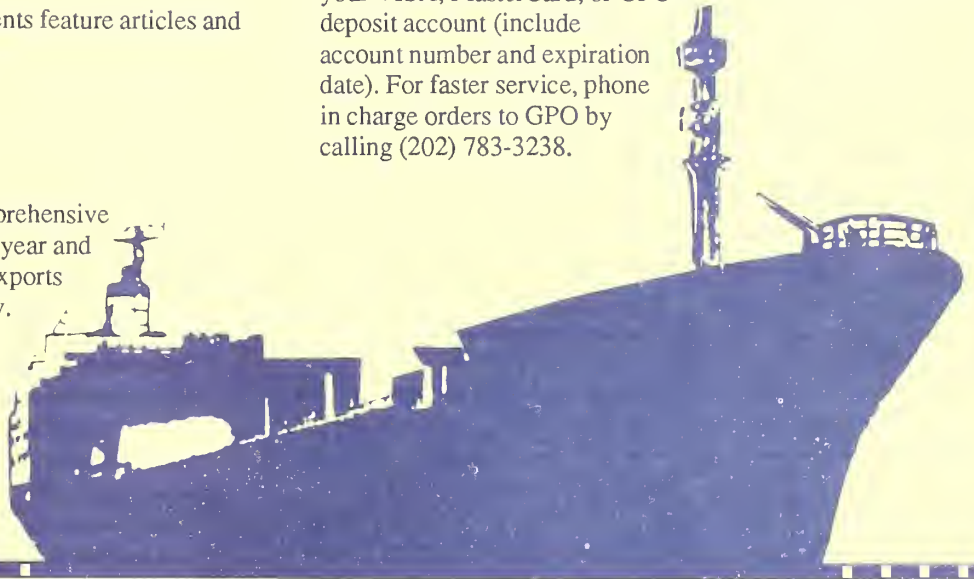
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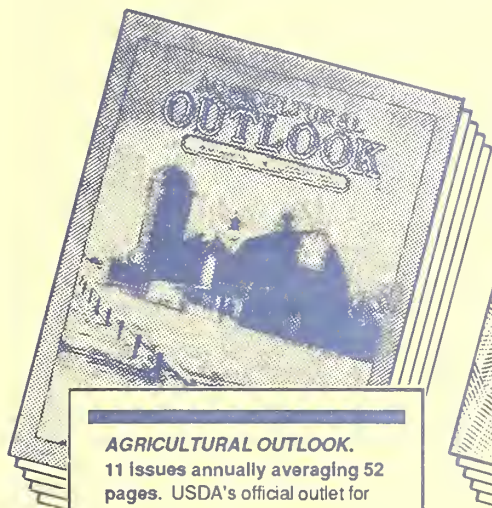
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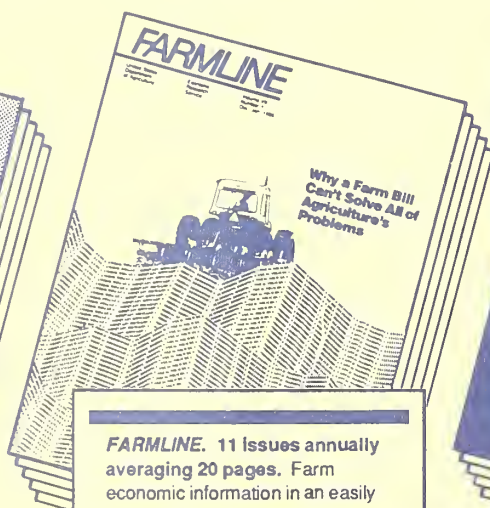


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